THE JULY SCIENTIFIC MONTHLY

Edited by

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NEW BOOKS OF SCIENTIFIC INTEREST

Giovanni Marliani and Late Medieval Physics. M. CLAGETT. 182 pp. $2.50. May, 1941. Columbia.

This book is a study of the life of Giovanni Marliani, an Italian physicist of the fifteenth century. His work and publications on problems of heat, kinetics and mathematics are analyzed, both in reference to the knowledge of his time and to modern concepts.

Textbook of Chemistry. A. L. ELDER. Illustrated. viii + 751 pp. $3.75. 1941. Harper.

This book is intended for students desiring a good foundation in general chemistry irrespective of their previous training in the field. The subject is approached through physical chemistry, the opening chapter being devoted to atomic structure.

A Complete Introduction to Photography. J. H. GABLE. Illustrated. xiii + 270 pp. $3.00. 1940. Harper.

A non-technical introduction to photography as an art and a science, this book includes presentations of the theory of photography, picture-taking, and dark-room work, concluding with chapters forming a "laboratory manual." Several photographs illustrate points in the text.

Development of the Sciences. Edited by L. L. WOODRUFF. 336 pp. $3.00. April, 1941. Yale.

The purpose of this book is to form a short introduction to science, its methods and ideas, background and trends. This presentation by eight men on the faculty of Yale University is not technical but is designed for the general reader.

Sea Power in the Machine Age. B. BRODIE. viii + 466 pp. $3.75. June, 1941. Princeton.

This book deals with the strategic and tactical changes in maritime warfare produced in the last century and a half, and the results of those developments in the political relations of nations.

Animal Behaviour. The Late J. A. LOESER. Illustrated. x + 178 pp. $2.00. 1940. Macmillan.

The author, formerly of the University of Berlin, has made a series of observations on animal behaviour. The book is composed of sections describing animal impulse in relation to self-preservation, propagation, migration and society, with the author's conclusions concerning animal instinct and intelligence.

The Audubon Guide to Attracting Birds. Edited by J. H. BAKER. Illustrated. xviii + 268 pp. $2.50. Doubleday, Doran.

This volume is intended to fill a niche in an educational approach to the subject of attracting birds to man's home, and to form a handbook of conservation, centering about, but not confined to, the popular appeal of birds.

Mask of Sanity. H. CLECKLEY. 298 pp. 1941. Mosby.

A study of the type of personality disorders which are not generally considered to be insanity, but which nevertheless prevent the individual from carrying out a normal pattern of life. Nine of the twenty-five chapters are devoted to detailed case studies.

What Price Alcohol? R. S. CARROLL. xv + 362 pp. $3.00. 1941. Macmillan.

A discussion of the reasons for persons being impelled towards alcoholism, of the effects of alcohol on the individual and upon society, and of the present day methods for the treatment and cure of this condition.

The Antarctic Ocean. R. OWEN. Illustrated. 254 pp. $3.00. 1941. Whittlesey House.

An explorer's attempt to show what the Antarctic is like, what its history has been, what its future will be, its character in general, and how slowly and painfully what little we know of these regions has been learned.

Arizona Indians. J. MILLER. Illustrated. 59 pp. $1.00. 1941. Hastings.

A collection of fifty portraits representing the following tribes: Navajo, Hopi, Apache, Havaspai, Yuma, Hualpai, Cocopah, Mohave, Chemehuevi, Paiute, Maricopa, Pima, Papago, Yavapai, and Yaqui. A six page account telling briefly about each tribe introduces the portraits.

Toughen Up, America. V. G. HEISER. vii + 228 pp. $2.00. April, 1941. Whittlesey House.

A book on the maintenance of health written for the layman by a physician. The author discusses food and dieting, sleeping, exercise, habits and other factors upon which health is based.

In Great Waters. J. DIGGES. xix + 282 pp. $2.50. 1941. Macmillan.

An analysis of fishing and whaling off the coast of New England from pre-Columbian days down to the present time. The source materials are primarily old memoirs and ship's logs, as well as stories gathered first hand from living seamen.

McGillycuddy, Agent. JULIA B. MCGILLYCUDDY. Illustrated. 291 pp. $3.00. March, 1941.

The biography of Dr. Valentine T. McGillycuddy by his second wife. He was a pioneer in the Mississippi Valley and one of the first physicians of the West. He played a prominent role in the relations between the Indian and the white man during the nineteenth century.

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JULY, 1941

ZOOLOGICAL GARDENS. I.

By Dr. ETHAN ALLEN ANDREWS
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Introduction

Time was when civilized cities had no electric light, no public baths, no public museums, nor libraries, but now these and many more are the common property of the people, who enjoy aids to the development of both body and mind undreamed of but a few years ago.

On the one hand we have our city golf courses which the weary factory worker may use, if he can afford the time and the rig; on the other hand, the symphony concert at cost price for those who prefer it to church: the city will fain feed all the desires of its citizens, to keep them in physical and mental health. Every city sees the advantages of parks; parks for air, for rest, for recreation, for music, for esthetic enjoyment of plants, grass and sky, for relief from the heat of midsummer nights in cramped house space. Amongst the luxuries of the city park may be the opportunities for pleasure, wonderment, education and relief from care offered by the modern zoological park—no mere menageries or set of cages and unhappy inmates, but the real garden with its strange animals of all climes living as if at home but protected from enemies, well fed and happy in exercise, bringing forth abundantly after their kind, living longer than in their native wilds, often in large enclosures without bars, apparently free, but harmless to the lookers on who can see and photograph them with nothing between but the impassable moat.

In such zoological gardens one may also see the aquarium full of the fish like those one almost caught, see them as they can not be seen in pond or stream, not from the top nor from the flapping, dying, gasping result of hook fishing, but from the side as other fish see their friends, with all the strangeness of life under water free from weary weight and tired feet.

To be sure, many cities have no zoological gardens as yet, but zoological parks are no new fad of the present day, and their reason for existence lies very deep in the make-up of human life. At one time the possession of the king, the zoological collections have become the possession of the people, and this democratization will go on till every large collection of peoples will have its living library of plants and animals left over from the wild. The wild will be no more and all its wondrous life must perish utterly except what is, for a season, hoarded up in dry museums or brought under domestication for the direct physical good of man, or harbored and bred in zoological parks for the better spiritual growth of a civilization doomed to see the boundaries of the natural world narrowed more and more by man's destruction of so much that was there before he came and can not survive unless he will it.

How many zoological gardens are there to-day? More than one hundred of all sizes and grades of excellence.

Courtesy of Friede.

SIXTEENTH CENTURY PAINTING OF ANIMALS ENTERING THE ARK
BY GERADE DE JODE, FROM "THE BIBLE IN ART" BY CLIFTON HARBY.

Where are they found? In Japan, two; in China, none; in India, one; in Egypt, one; in Africa, three; in Australia, four; in New Zealand, one; in Italy, one; in Austria, one; in Hungary, one; in Switzerland, three; in France, four; in Germany, nineteen or so; in Holland, three; in Belgium, three; in Russia, two; in Great Britain, three; in Ireland, one; in Denmark, one; in Norway, one; in South America, four; in Canada, three; and in the United States, perhaps twenty.

Thus the far from ancient civilization of the United States has adopted these old world ways of pleasing the people and in some cases has arrived at the head of the procession.

In these days of imagined history underlying written records, when the "squatting place" ranks with the "tower of Babel" as well-known epochs in man's advance, it is not difficult to imagine how man and animal became first joined with bonds that still make him yearn for his old comrades of the wilds. Man enters the present day zoological garden as necessary observer, a most essential inmate, but when man first appeared on earth he was but an interloper, a strange new inmate of the great garden where he encountered such strange fellow creatures. These he had to observe and study, for upon them depended his very existence and they were his first animate teachers to sharpen his wits, until he gained more and more dominion over them.

Many first men did not survive and many, very many, of his contemporary fellow animals did not survive, but some few men and animals continued on together and to-day he likes to see these strange creatures that did not outdistance him in the contest of wits.

Paleolithic man was buried with his dog; neolithic man left behind him his horses, sheep, cattle, pigs and goats.

Beginning as hunter, he passed gradually to the stage of property holder and domesticator of the wild.

The Zoo started in the home; the

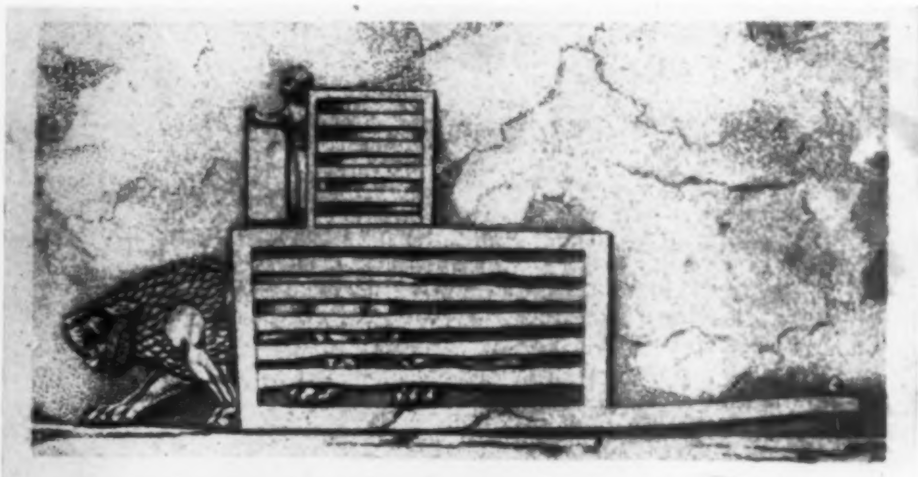
hunter bringing back the living young of the hunt, appealing to the best in him by their helplessness, their winsome gambols, as well as by their subjugation to his will. Some remained as companions, others as beasts of burden; others were useful for the wonderment and reverence they called forth.

Evidently the poor fish fared worst of all in seeking man's protection in the farm, household or zoo; and for the very reason that makes the fish so intensely interesting to the modern man sufficiently educated to take pleasure in the household aquarium: the fish lives in water; the man must soon come out into the air. Primitive man had no glass globe; the fish perished before they were well seen. To-day we see the fish on our level as one of us, yet living where we have not yet learned to live easily. The bird could be caged; the fish was the unknown mystery never caught in the full measure of its wonderfulness.

However great the gulf between man and beast, the fact remains that they have much in common; what man does, one or another animal has done to some extent. The association of animal with animal is by no means limited to those of the same kith and kin: see the remarkable present-day Paradise screens taken by the lenses of Shilling in Africa, showing the great herds of most diverse animals all living in one another's company. "*Symbiosis*," the living together of different creatures without harm, one to the other—that is, the fundamental fact in all nature, equally fundamental with the facts of destruction and contest.

Many marvelous chapters of biology tell of the living of animals with quite different animals, of plants with plants, of animals with plants and of plants with animals of all kinds, sizes and grades of being, and in all grades of freedom, and of intimate combination until the companions seem to make but one individual.

Among the ants, whose social communities show some points of resemblance to those of men, there are innumerable cases of "symbiosis." There are cases where the ant harbors in its home most diverse little animals, some to be carried about and tended and reared for the milk-like food they let out for the ant, others tolerated as rats and mice



CAPTIVE LION BEING LET OUT OF A PORTABLE WOODEN CAGE

EN ROUTE TO AN ASSYRIAN HUNT. FROM WALL CARVING NOW IN BRITISH MUSEUM; ALSO DRAWING IN LOISELL'S HISTORY OF MENAGERIES.

MOTHER POLAR BEAR GUARDING FOUR MONTHS' OLD CUB

IN THE ZOOLOGICAL PARK OF MILWAUKEE. THIS CUB WAS BORN LIKE MANY OTHERS IN THIS PARK WHERE THE MOTHER ADHERES TO HER NATURAL INSTINCTS TO GO INTO RETIREMENT IN THE AUTUMN AND NOT PERMIT THE YOUNG TO EMERGE FROM COMPLETE ISOLATION TILL MARCH.

about human homes, others overlooked like the kitchen cockroach, others actually enjoyed as man enjoys his hothouse plants, it would seem.

Estimates running ahead of the actual counts of 1,500 kinds put the probable number of species of animals living in the homes of various ants as 3,000.

Even the keeper of a great zoological park, who should also be a farmer and have a house full of insects, may not come into contact with so many diverse creatures as may the ants in their homes.

Granting that the tolerance of other animals is deep set in ant and man and that the hunter saved out the foundations of future house pets, farm animals and menageries, what can be said of recorded steps in the actual history of menageries and zoological gardens?

Zoos of Antiquity

The ideal setting for man is the garden, but when man becomes men, neither the flowery garden of the cottage in New Zealand or the public park of the modern city can quite replace the imagined golden age of primitive man with the question of land ownership yet unborn.

And Jahweh planted a garden in Eden, in the East, and placed there the man whom he had formed. And Jahweh made every tree that is pleasant to the sight and good for food to spring from the ground.

And Jahweh formed out of the ground every beast of the field and every fowl of the heaven; and brought them to the man to see what he would call them, and whatever the man called them, that is each living creature, that was to be his name. . . . And the man gave names to all cattle and to the fowl of the heaven and to every beast of the field; but for a man he did not find a help corresponding to himself.

Imagine the bliss of this first naturalist in seeing and hearing enough of all this incomprehensible zoo to give to each its appropriate name. How the first visitors suffered the penalties of not obeying the rules of the zoological garden we know full too well, as Milton describes them.

It was ages afterwards that the first traveling menagerie or transportable zoo was builded by good old Noah, escaping the excessive dampness that has ruined many other zoological collections:

And Jahweh said to Noah: "Come thou and all thy house into the ark. Of every beast that is clean thou shalt take seven pairs, the male with his wife; also of the birds of the sky seven pairs (the male and his wife) to keep seed alive on all the face of the earth."

Thus it came about that all later zoological parks have been stocked from the original Paradise park, while animals that later escaped remained wild to contest the lordship of man.

Save me from the jaws of the lion,
My wretched life from the horn of the unicorns.

The mighty hunters of antiquity soon learned to preserve the beasts of prey for the sport of killing them on occasions.

Daniel in the pit, or den, of lions probably found himself amidst beasts stored up for future hunts.

The Persians kept extensive "Paradises" or parks where were held for future sport in hunting, lions, tigers, wild boars, antelopes and other creatures: a zoological garden with chiefly the king to enjoy it and each animal doomed to sudden death when, for instance, the slaves took out, say a lion in a cage, and released it that the king might overcome it with arms and courage.

Erman, in "Life in Ancient Egypt," describes the men of those days as having a passionate love of the chase, the wealthy at all times keeping menageries in which they reared the young animals taken in the hunt in the desert with lassos or with dogs. They also kept animals brought into Egypt in commerce or as tribute, for in those days the rare wild animal was a precious gift or gold substitute.

They brought in lions, leopards in great cages, hyenas, gazelles, ibex, hares and porcupine from the desert; and

AFRICAN ELEPHANTS AT HOME, AS CONCEIVED BY JOSEPH WOLF
FROM STUDY AT THE LONDON ZOO TO WHICH THE FIRST AFRICAN ELEPHANT, JUMBO, WAS BROUGHT IN 1865, TO STAY UNTIL 1881, WHEN IT BECAME TOO IRASCIBLE AND WAS SOLD FOR TEN THOUSAND DOLLARS TO BARNUM FOR EXHIBITION IN THE UNITED STATES.

from the upper Nile, the pard, baboon, giraffe; and from Syria the bear and the elephant.

But not only were the animals hunted to death; there were those who tamed and taught them tricks. Rameses II was followed to battle by a tamed lion that lay by his tent at night. Pet apes were imported and became the favorites of ladies.

Actual descriptions of animals and the mighty kings who hunted them may still be read on Assyrian and Babylonian monuments and supply the best of evidence of the state of the zoological garden in those, its embryo days.

From the papers of Bruno Meissner we gather that on the Prism of Tiglathpileser I are carved the statements that he was a most successful hunter, boasting of the wild animals he had slain, and that he brought back great numbers of wild animals and not only kept them in captivity but got them to reproduce. He also went out to sea, in the Mediterranean, and killed a sperm whale "that blows out of the nose hole," whose teeth were used in place of ivory.

These kings were not unmindful of the popular pleasure in exotic animals and made use of this as a means of showing off their supreme power. Tiglathpileser showed the people herds of "trample-thiere" and let them revel in the sight of the gifts sent him from the Pharaoh of Egypt, a great ape, a crocodile, a river man and animals of the great seas.

Not only did this monarch keep the native wild beasts in his gardens, but he was successful in acclimatization experiments, bringing into his country the cedar of Lebanon, as well as elephants and wild oxen.

It was said of him that he hunted in the days of frost and rain and caught in nets both male and female wild goats and deer and kept them in his herds until they reproduced. Apparently these

herds were kept in great parks where they could be hunted. But he also sent merchants to buy dromedaries and these he bred in herds and showed them to the people. He thus laid the foundations of zoological gardens, *three thousand years ago.*

Another mighty hunter, Assurnascirpal, says:

> I killed with the bow 30 elephants, 237 mighty wild bulls; I killed from my war chariot in royal battle, 370 mighty lions; I killed with my spear, like caged birds.

This nimrod brought together a fine collection of animals and distributed them amongst the parks of his various palaces, thus forming definite zoological gardens. The fine carving of this king shows three horses galloping over a wounded lion with three spears in its body, while the king in the chariot draws his bow and another man drives the horses. Do we see in this pictured lion one actually saved and kept for the zoological garden of that period, 885–859 B.C.?

This King and Salmanassar III had pictures made on stone obelisks representing the wild apes, elephants, camels with two humps, aurochs. And possibly stuffed skins served to convey some of the lessons of the modern museum; and at all events there seem to be inscriptions complaining of deceit in the representation of the wonders of exotic animal life.

Assurnascirpal records his successes with the same lack of false modesty seen in some great hunters of African beasts, in very modern times. His recorded statements on stone are supposed to say:

> On the other bank of the Eufrat river I killed fifty wild oxen and caught 8 living . . . with my strong hand I caught 15 lions in the forests and mountains. I took fifty young lions and put them in cages in my palace and their young greatly increased in numbers. I seized living mindin with my hands. To my city, Kalach, I brought and showed to my people: herds of wild oxen, elephants, lions, lurmu birds, male and female apes, wild asses, gazelles, deer, pards, and sinkurri; all sorts of animals of the plains and of the mountains.

Surely does history repeat itself, but

BEARS IN A MOATED ENCLOSURE WITH NO BARS TO KEEP VISITORS OUT
AS SEEN IN "THE WORLD'S FINEST ZOOLOGICAL PARK" AT ST. LOUIS. MANY OTHER ANIMALS ARE ALSO SHOWN IN MOATED ENCLOSURES. THE VISITORS SAFELY, AT CLOSE RANGE, SEE THE ANIMALS MUCH AS IF IN THEIR NATIVE HABITATS.

FEEDING A CAPTIVE PORPOISE UNDER WATER IN HUGE TANK.

OF ALL THE MAMMALS, THE WHALES OFFER SOME OF THE GREATEST OBSTACLES TO CAPTURE AND CONFINEMENT IN ZOOLOGICAL PARKS, BUT AT LENGTH THESE SMALLER MEMBERS OF THE WHALE TRIBE HAVE BEEN TAKEN AND KEPT WITH SUCCESS; AT LEAST ONE WAS BORN IN CAPTIVITY.

present democratic spirit makes the Roosevelt Wing of the American Museum of Natural History a rather different factor in education than were the great collections of this royal hunter of Assur.

This policy of combining the king's pleasure with that of the people in the matter of zoological gardens was followed by his successor, Salmanassar, who imported rare plants and animals. On the "black obelisk" are depicted the figures of animals sent him as tribute: camels with two humps, oxen (perhaps the aurochs), an antelope, animals with horn between nose and forehead, and great apes walking or being carried.

A still later monarch boasted that at the command of God there grew in his gardens various exotic trees and fruits, better than in their native lands, while the wild swine and other animals gave birth freely and the bird of heaven (the swan?) built its nest, although its home was in far distant lands.

Thus in the Assyrian civilization, zoological gardens of some sort were to some slight extent engaged in by the people, but far less so than at present when even the most dictatorial park board would hesitate to import animals without some reference to the vox populi howling in the press.

Flower, the director of the Zoological Park near Cairo, states that the ancient Egyptians had zoological parks.

But other civilizations found the need of zoological gardens as culture advanced. But here we lack stone monuments and inscriptions for the first beginnings. Yet it is stated in encyclopedias that in the old Chinese civilization, in the China (which began and invented everything and then forgot all about it in the centuries that passed), in China, which to-day is so denuded of its former wild life and so pleased with its gold fish, china images and grotesque dogs that there is little interest in the zoological park; in this China in the year 1150 B.C. the "Park of Intelligence" was maintained by the great founder of the Tscheu dynasty at Lin Yo. This great zoological park, where the Emperor was pleased to walk to view the animals enjoying themselves as in their native wilds, contained mammals, birds, turtles and fish.

It was then a comprehensive collection appealing to those who loved bird, beast and fish. If, as is stated, this garden endured on into the fourth century, B.C., it outranks in age of existence all the zoological gardens that have ever started, although of course some now existent *may* last as long.

How very ancient the civilizations of America may prove to be remains yet to be determined; but it is interesting to learn that on this continent also zoological gardens came to be recognized as part of the higher culture. Montezuma, the last of the Aztec leaders in Mexico, had a menagerie in one of his pleasure houses, where there were a long series of aquaria of water containers, bird houses and cages, wild animals, birds from all parts of the realm, from giant condors to pigmy humming birds. There were also snakes and lizards. Both salt water and fresh running water was provided in this zoo.

So great was the collection that 300 attendants were working to care for the animals and to collect feathers for the artistic mosaic work carried on in this connection.

This was not the only zoological collection of that country. Both the contemporaries and the forefathers of Montezuma maintained similar menageries.

History of European Menageries

European civilization, with its long series of interactions of princes, church and people, has also developed the zoo-

EIGHTEENTH CENTURY VIEW OF A PRIVATE MENAGERIE
BELONGING TO JAN A. BLAAUW OF AMSTERDAM, IN WHICH THE VISITORS ENJOY INTIMATE ASSEMBLY WITH THE BIRDS AND MAMMALS WHILE PARTAKING OF REFRESHMENTS, THUS FORECASTING THE ASSOCIATION OF ZOO AND RESTAURANT LATER SO PREVALENT IN MANY COMMUNITIES.

logical garden, from the toy of the king or churchman to the possession of the city and its people.

From the publications of the old zoological society of Frankfort, Wilhelm Stricker has collected the following statements that show the slow advance in the status of the zoological garden in various states of Europe.

If there be any truth in the idea that Aristotle had for study collections of animals sent him by Alexander the Great, these were surely not connected with zoological gardens, and the same may be said of many collections of wild animals brought together by the Romans for feasts and spectacles of the arena.

But as early as the tenth century we are told the zoological collections of the Monastery of St. Gallen, site of an Irish hermit's dwelling, contained both native animals and those from a distance, such as bears, badgers, marmot, wild goats, deer, silver pheasants. Some of these were donated by visitors.

Other religious houses also found the zoological park a welcome addition to their means for contemplation and intellectual activity.

In 1408 the grand master of the Teutonic order at Marienburg received a lion as a present and this was added to his zoological garden—his menagerie—with deer, bears, apes of different kinds, as well as "sea cows" and "sea oxen" (?), and large wild cattle, four of them the present of the Prince of Lithuania.

Some of these animals, the apes, were taken into the house at times, while outdoors there were also large enclosures for rabbits. Other grand masters kept rabbits, and the gift of these animals was a common courtesy.

In the sixteenth century the menagerie

of the grand master, later the Duke of Prussia, served as a source for animals that were sent to other zoological collections. Thus in 1518, fine aurochsen (*Bos taurus*) were sent to Brandenburg and to the King of Denmark. Animals again served, as in Assyria, for gifts and tribute.

The Emperor, Frederick II, received from friendly rulers of the East both lions and tigers, leopards and camels, as well as giraffes. The cities also began to please the people with exhibitions of wild animals.

In 1399 Frankfort had collected some deer, but this was a very modest beginning, and in 1400 there were but two animals, one the present of the Jew, Gottschalk von Kreutznach; but in the eight years they had increased so that the yearly feast of the city council did not keep down the deer sufficiently, and in 1444 the council gave some of the deer away to certain zoological gardens, as at Munzenberg. This experiment in city park breeding of deer was, however, abandoned in 1556 and so did not lead up to the present zoological park of the city of Frankfort.

The town of Berne, Switzerland, had six bears in 1551. Down in the Netherlands the appreciation of the animal collection was early shown. In the fourteenth century the woods of the Count, The Hague, contained buildings for dogs, falcons, fowl and also lions, bears, dromedaries. Other princes had their collections and maintained special masters of fowls, parrots and birds. At Rosendaal, in the year 1398–1399, the lions in this garden consumed a total of 260 sheep. Previously, in 1384, as many as 200 wolves had been used for the same purpose inside of five months. But all expenses were not so great, for we read that the man who took care of the lions received but two grotes a day in 1664!

Amsterdam, the city, had its own collections and received lions as presents from merchants—two from Spain in 1488 and two from Portugal in 1483. A few years later Amsterdam gave five or six of its lions to the city of Luebeck. Ghent also had its collection of lions.

While these royal beasts were being handed about between cities and princes, other gold substitutes were found in the rare and bizarre parrots, a sort of animated greenback, the council of Nuremberg paying out fifty pounds in 1458 to send a parrot to the Bishop of Mainz, and sixty-five pounds in 1460 to send another parrot to the Queen of Bohemia.

At what date the elephant appeared in Europe as a show animal worthy of being a royal gift is difficult to find out, but in 1551 Maximilian II brought into Germany from Spain a male elephant and used it in the triumphal entry into Vienna, in 1552, as King of Bohemia. But before that several inns had been called "The Elephant"—one in Strassburg, 1343; one in Frankfort, 1404; and it was said that an elephant had been exhibited in Frankfort in 1443 or 1480.

The royal menageries of Austria laid the foundations for very important developments in zoological gardens. At Ebersdorf, near Vienna, Maximilian, the eldest son of the Emperor Ferdinand, had a menagerie which was much enriched by the addition of foreign animals brought in by the enthusiasm of Rudolf II (1552–1612) who, however, let the collection die out while he started a second menagerie about 1570 at Neugebau. This second collection was maintained and enlarged by Leopold I and in this period of the history of the garden occurred the tragic episode described in Chamisso's poem, "The Lion's Bride."

Although the Hungarian rebels destroyed this collection in 1704, it was started again in 1738 by Karl VI, who added to it the lions he got from the collection of Prince Eugene, at his death in 1736.

But even this second attempt was

WATERFOWL LAWN AT THE LONDON ZOO IN 1830
WHEN VISITORS AND THE BIRDS ON DISPLAY APPEAR WELL SATISFIED WITH THEIR COZY ASSOCIATIONS.

abandoned in 1781 and did not continue on to the present day, even though it had been thus permanent for two centuries.

Ebersdorf and Neugebau may be cited as the first and second names in the long list of European menageries or zoological gardens.

A third name, also in Austria, is that of Belvedere, where the above Prince Eugene started in 1716 a menagerie which, although not long enduring, had in it a fine old bird of prey, *Gyps fulvus*, that lingered on in captivity to the very old age of 117 years, and died just before 1824.

Important amongst these old royal menageries was the one at Dresden, which was started in 1554 as the royal Polish collection and increased and well kept up so that the King, in 1731, sent out to Africa a scientific expedition to obtain more animals for this large zoo.

During all this time zoological gardens had sprung up in other parts of Europe; between 1673 and 1730 there were menageries at Cassell and at Karlsburg, and one at Potsdam in 1702.

In this eighteenth century also there began those collections of wild animals in England that for a time satisfied the popular demand but later blossomed out as the great collections of the Zoological Society of London.

Already, in 1761, the Tower of London contained a menagerie of lions, tigers, leopards, hyenas, apes and birds, including an ancient eagle that lived ninety years in captivity; this was not the fate of many another biped confined in the Tower.

The early beginnings made in Austria were not by any means lost, but were gathered up in a new royal menagerie lasting down to our times, so that in 1907 the Emperor of Austria paid out some 258,400 crowns to support his private menagerie of 363 mammals of 160 species, his 1,351 birds of 345 species, and his 171 reptiles of 47 species. The origin of this very romantic and elegantly housed collection which became

associated with some great events of history was as follows:

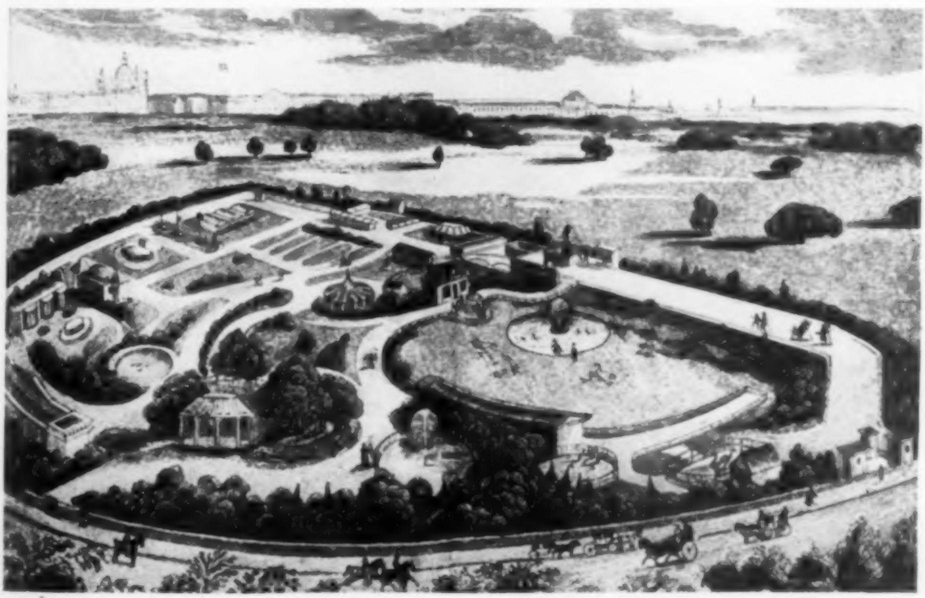
At Schönbrunn, in 1752, this famous royal zoological collection began when the Emperor Francis I and the Empress Maria Theresa brought in the services of the landscape gardener, Adrian von Steckoven of Holland, to plan out a garden along the lines of that of the animal lover, Prince Eugene of Savoy. A remarkable creation of solid walls thirty feet high and buildings thus arose in the forest. To this were brought all the wild animals housed in the Neugebau collection and in the Belvedere collection, and to these were added many new purchases from Holland and from England. For this great zoological garden the Emperor also sent Nicolas Jacquin in 1754–59 to the West Indies, and to South America to collect plants and animals for his garden.

In 1759–60 the royal pair built in the midst of the garden an octagonal house, where in the summer time they took their breakfast and looked at the live animals from the windows and doors, or at the walls adorned with paintings.

To maintain and strengthen this imperial menagerie, the Emperor Joseph II took away from the Neugebau collection all the remaining animals and added them to Schönbrunn in 1781, and moreover sent out two scientific expeditions to North America and to the East Indies in 1783–85, followed up in 1787–88 by expeditions to South Africa, Isle of France and Bourbon to add to his great private zoo.

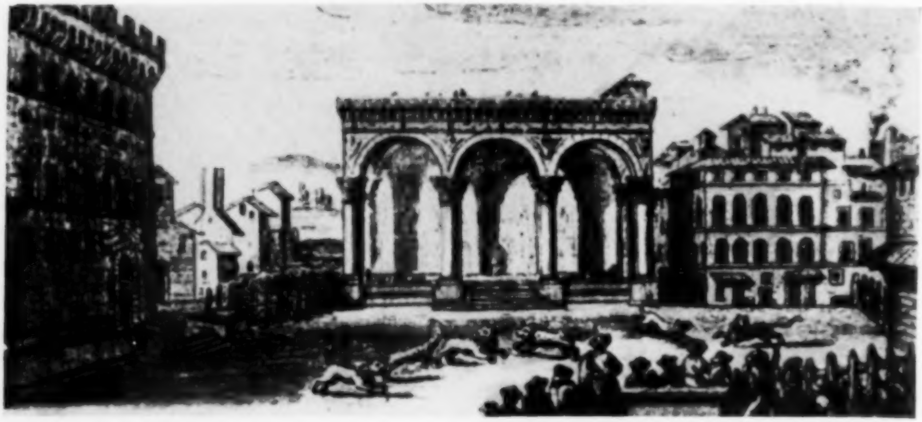
Francis II rebuilt the menagerie of Schönbrunn, buying up traveling menageries in 1799, 1824, 1826, and added also the collections brought back by the Austrian expedition to Brazil.

In 1828 the giraffe sent to Vienna as a present from Mohamet Ali appealed



PLAN OF THE GROUNDS OF THE ZOOLOGICAL SOCIETY OF LONDON

IN ITS EARLY DAYS, 1829, WHEN AS PROPERTY OF THE SOCIETY IT WAS OPEN ONLY TO MEMBERS AND SUCH OF THE PUBLIC AS OBTAINED CONSENT OF MEMBERS. AT THAT PERIOD IT WAS SAID "THE VULGAR ARE TOO FOND OF IRRITATING THE FIERCER ANIMALS AND OF TEASING AND OF HURTING THOSE THAT ARE GENTLE."



LIONS KEPT IN ONLY PARTIAL CAPTIVITY IN COURTYARD OF OLD PALACE

FLORENCE, FIFTEENTH OR SIXTEENTH CENTURY. THUS THE BARLESS ENCLOSURE FOR WILD CARNIVORA HAD ORIGIN FAR BACK OF THE INVENTIONS OF CARL HAGENBECK AND MODERN USAGE. IT IS EVIDENT THAT THE VISITORS COULD ENJOY FULL VIEW OF THE LIONS AND WITH SAFETY, ESPECIALLY IF ON TOP OF THE TALL BUILDING, WHILE THE LIONS SEEM TO REJOICE IN ABSENCE OF BARS BETWEEN THEM AND THE SKY.

greatly to the imagination of the Viennese and became the subject of much literature and started a fad for giraffe-shaped pianos, giraffe hair combs, giraffe hair dress, etc.; but the giraffe died after ten months and thirteen days of deification.

At one time this famous Schönbrunn collection was subdivided in the making of two specialized Vienna menageries, but it was again restored and enlarged by purchase of traveling menageries by the Emperor Ferdinand I in 1837, and the next year was made more useful to the public by the addition of signs bearing the scientific name and the country of origin of each animal.

Thus it continued, becoming more and more open to the public, although a private possession of the Emperor, with sometimes the need of restricted use when abuses followed too great freedom of access.

Thus the playthings of kings may sometimes be shared by the people.

So it fared in France likewise, where the great museum and zoological park, the "Jardin des Plantes," coddled in infancy by the King, becomes, full grown, the school of the republic.

It seems that Louis XIII entrusted his two physicians to purchase twenty-four acres of land and buildings for the *culture of medicinal herbs*, in May, 1636.

Under Louis XV, in 1732–30, this royal garden was rejuvenated by its director, Dufay, who gave to it his own collections and brought it about that the great zoologist, Buffon, was appointed as his successor in 1732.

This was the zenith of success of the royal garden: Buffon, Daubenton, Bernard de Jussieu and later Lurent Jussieu, Rouelle, Fourcroy, Lavoisier, Winslow, Portal and others made of this institution, up to the time of the Revolution, the leading scientific institution of the world.

But, however successful, this combination of king and scientists was temporary. Buffon died on the eve of the Revolution, April 16, 1788.

In 1790 the royal garden was taken away from the king, but it was decided to continue it enlarged as the Museum of Natural History, to which in 1793 a

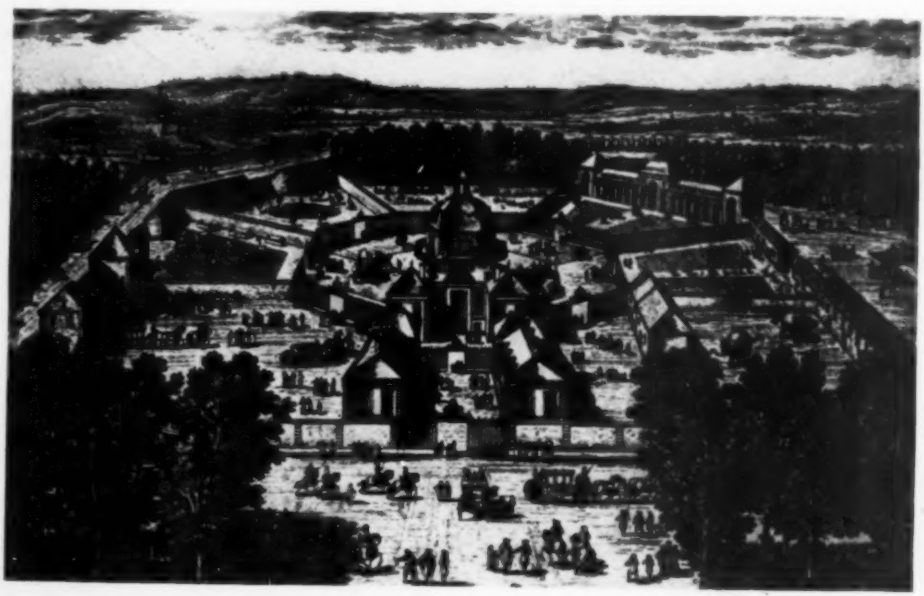
menagerie was added, as suggested by Buffon, by the foundation of a library and museum of natural history, opened on September 7, 1794, with an annual appropriation of some $30,000. At this same time the royal menagerie, founded by Louis XIV and made larger by his successors, was taken away from Versailles and added to the garden by the efforts of Bernadine St. Pierre after much discussion of the best way to house the collection at Versailles after the destruction of royal power, September 21, 1792. Although the mob had destroyed much there were still the remarkable animals, a quagga, a hartebeest, a crested pigeon from Banga, an Indian rhinoceros and a lion from Senegal living in great friendship with a dog.

Thus did the old king's garden and menagerie of the palace unite with the museum and library of the commonwealth to make the unique zoological park ever since famous as the "Jardin des Plantes," for the Frenchman can not give up the old name, loving the form if not the substance of royalty.

The zoological garden in the old king's park was very popular and was soon rapidly enlarged by presents, by a shipload from Trinidad in 1796, by collections from Guiana and by an expedition to Africa in 1797 under Cassell.

Under the Consulate, the Jardin des Plantes flourished greatly and became a second time the center of scientific activity, publishing from its Museum of Natural History 20 quarto volumes of *Annalen* in 1802–13; 20 quartos of *Memoires* in 1850–; 14 quartos of the *Nouveln Annalen* in 1832–35; and ten quartos of the *Archives*, 1840–58.

As under the old régime, the garden had greatly aided Buffon in his great philosophical Natural History volumes, so that the new Jardin des Plantes was the chief support for the great work of Cuvier on the Animal Kingdom, which so deeply impressed the advance of science.



RADIAL ARRANGEMENT OF MENAGERIE OF LOUIS THE FOURTEENTH AT VERSAILLES, 1638–1715.

THE FAMOUS ROCOCO OCTAGONAL PAVILION WITH COPPER ROOF
BUILT IN SCHÖNBRUNN IN 1759, AS IT APPEARED TO LOISELL IN THE TWENTIETH CENTURY.

But gradually the garden got into financial straits so that Cuvier, as professor of comparative anatomy in the Jardin des Plantes, wrote, in 1800, that the members of the staff were twelve months in arrears in their salaries.

Here also labored Lamarck, the radical and original spirit in the zoology of the garden.

The lectures of Cuvier, given to large audiences with free-hand sketches and illustrative material from the collections of the garden, greatly added to the reputation of the Jardin des Plantes and means were found for sumptuous publications in natural history. For the first time many animals were well represented in pictures from life in colored copper plate published in the splendid folio, "*La Ménagerie du musée national d'histoire naturelle*," by Cuvier and Lacépede, in 1801; and this was republished and brought up to date in 1817 as two quarto volumes with 58 copper plates. The Emperor Napoleon added to the garden, tigers, lynx, mandrill, leopard, hyenas, panthers and birds and plants which he bought in England, and in his wanderings he remembered the museum with gifts of fossils and rocks from Corsica. One expedition brought in 100,000 animals, small and large, with a zebra and a monkey for the Empress Josephine. Other collectors returned from Lisbon, America, Italy and Germany.

The condition of the menagerie in 1823 may be read in a book on Paris and its inhabitants by Moeller, Gotha, 1823, pp. 210–216.

When Geoffrey Saint-Hilaire was professor of zoology in the garden in 1841, there were then museums of zoology, of comparative anatomy, of botany, of geology and of minerals, with a large library of 28,000 volumes on travels, natural history, botany, physics, chemistry, mineralogy, comparative and human anatomy and zoology.

Its condition in 1849 is related in the book of "Esquires and Weil," Stuttgart, and there is another account in 1861 in the "Journey of Dr. Weinland."

The menagerie in the garden received

much from Mohamet Ali, Pasha of Egypt, so that it came to have not only Arabian horses and antelopes, but an African elephant. Most astounding of all to the people was the giraffe sent by the ruler of Senaa, as the first to set foot on French soil. Taken young and reared on camel's milk, the journey was broken by three months in Cairo, and then continued to Marseilles by boat with three cows to supply the milk. Arriving on November 14, 1825, when twenty-nine months old, the young giraffe remained over winter to start on May 20, 1827, on foot to Lyons, where it arrived safely on June 5, and thence by short laps to Paris. Another giraffe sent then by the Pasha to England died at Malta. In France the giraffe made a stir, as had the first giraffe in Austria. A number of scientific papers show the excitement of this event.

Other giraffes fared less well. One died in Toulouse in 1844; another on the way to London died in 1829 from disease of the joints, perhaps arising from riding on camel's back with knees doubled up.

The Jardin des Plantes of the present century has recovered from the evil days when, in 1870, a hundred shells fell within it, ruining most of the glass houses, and when the animals were decimated that many might be used as food. Two African elephants ("Castor and Pollux"), two camels, four elands, all the stags, nilgais, etc., went to the butcher. Lion, bear and hippopotamus meat selling at five dollars a pound, and hard to get even at that price!

Here then we still have some of the old king's garden with fine old cedars of Lebanon, old museum collections of the times of Lamarck, Cuvier or Buffon, as well as a very popular free menagerie dispersed amidst fine trees and shade.

(*To be continued*)

A POSITIVE PHILOSOPHY

THE university can, however, contribute directly to national defense in a fourth field—the field of ideas. I do not mean that the faculty should embark upon a campaign of propaganda nor that in an effort to combat the political philosophy of Hitler we should incorporate his methods in our educational institutions. I am not suggesting a witch-hunt directed against those whose ideas do not coincide with ours. The principle of freedom to express ideas is sound now, in a period of emergency, as in normal times. But that freedom does not imply the desirability of a neutral attitude between what we feel is right and what is wrong. It does not divest the leaders in a university community from the responsibility for guiding the students and public opinion in the direction of what they believe to be right. During the past two decades our universities have suffered from a negative complex; our faculties have analyzed issues and balanced factors; they have exposed the follies and the vices of historical figures and movements; they have not emerged with a positive philosophy to which students and public might attach themselves. There is justice in the complaint of the undergraduate that his academic experience had not provided him with a faith.

Appreciation of values becomes most intense when they are in danger. It is likely that the present emergency will revive faith in our American way of life and enthusiasm for its preservation and development. The universities must take the lead in this resurgence of conviction, which alone can give to the nation a unifying force. They have been the first to profit by the freedom and security proceeding from our American system; they are the most keenly alive to the spiritual values that disappear in a totalitarian system; to them is entrusted the guidance of the youth of the land whose lot it is to defend and carry on the American tradition. This is a responsibility that has fallen upon our shoulders and which we can not evade. If it is properly fulfilled our young men will graduate with a flaming faith in the American ideal. No other contribution to national defense which we can make will be of equal importance.—*Report of the President, Yale University.*

LIVING GUIDE-POSTS OF THE PAST

By Dr. RAYMOND E. JANSSEN

GEOLOGIST, EVANSTON, ILLINOIS

THROUGHOUT the Mississippi Valley and Great Lakes regions, may be seen numerous curiously bent trees. The casual observer views them merely as deformed freaks; but careful observation and comparison of the nature of the deformities indicate that these trees did not acquire their strange shapes simply by accident.

These trees exhibit an acute or right-angled bend in their main trunks, usually from two to five feet above their bases. Rising vertically from the bent trunks are one or more lateral stems, or secondary trunks, bearing the branching structure and leaves. Ages of the trees range from somewhat more than a hundred to two, and three, hundred years.

FIG. 1. STURDY OLD BURR OAK
ALTHOUGH ABNORMALLY CONTORTED, IT EXHIBITS ALL THE STATELINESS OF ITS SPECIES. IT IS SITUATED NEAR THE CHICAGO RIVER, NORTH OF GLENVIEW, ILLINOIS.

Although these trees have been growing in their respective situations for long periods of time, no reference concerning them may be found in previous scientific literature. Scattered historical references, however, indicate that trees were sometimes bent by the Indians to mark trails through the forests. Consequently, a study was carried on over a period of several seasons for the purpose of determining whether such trees still standing might have been deformed intentionally by Indians who formerly inhabited mid-western America.

This study indicated that the use of trees for trail markers was a custom apparently inaugurated by the forest inhabiting natives of North America long before the advent of the white man. The custom arose, no doubt, because trees were the most accessible and most easily adaptable materials at hand. Because of their flexibility, living trees could be contorted into unnatural shapes, and being rooted they could not easily be removed. Also, by using a few trees out of many, the Indians could make these markers as conspicuous or as inconspicuous as desired; hence trees made ideal guide-posts.

In order to establish certain trees as markers, the Indians inhabiting wooded regions developed the custom of bending saplings and fastening them in position in such a way that they became permanently deformed. A long line of similarly bent trees could thus be followed by proceeding from one bent tree to the next. Once a trail was established, the Indians could follow these markers through swamplands or across difficult

terrain without unnecessary delay, and could maintain their direction while traveling long distances through densely wooded and unfamiliar territory.

Observation had taught these primitive people that trees do not heighten *en masse* nor turn on an axis. They noticed, too, that trees when once deformed maintained their deformities throughout subsequent periods of growth. Thus it became possible to deform trees deliberately in order to distinguish them from the ordinary trees of the forests. In bending the young trees, care was taken so as not to break them. As a result they did not die, but continued to grow in the deformed positions. Whether by accident or intention, by deforming living trees, the Indians left behind them a series of permanently marked trails. Although a hundred years and more have elapsed since the Indians were forced westward from the Mississippi Valley by the advancing white man, their old trail markers may still be growing just as they were when first established so long ago.

It has been found that various methods of securing the saplings in position were used, depending on the materials at hand and the custom or ingenuity of the individual performing the task. Sometimes the trees, after being bent, were weighted down with a rock if one could be found nearby. Occasionally they were staked; sometimes a pile of dirt was used. But more frequently the trees were tied in position with a strip of rawhide, bark or tough vine (see Fig. 3).[1] In each case the trees were fastened so that the direction of bend was parallel to the direction of the trail to be followed. Each tree was thus a pointer directed toward, or away from, the next marker in the trail.

As might be expected, the deformation

FIG. 2. AN INDIAN MARKER
IN WILMETTE, ILLINOIS. IN REGIONS WHERE INDIAN MARKERS STILL EXIST, THEY MAY OFTEN BE SEEN ALONG THE STREETS OF TOWNS.

of saplings had a serious effect upon their subsequent development. The trunk and branches which had previously held the leaves up to the sunlight were suddenly distorted earthward, and hence could no longer function normally. Compensation for this unnatural position, and resumption of normal growth, occurred only after new vertical branches—secondary stems—began to appear along the bent primary trunk. During this readjustment period, growth was much retarded, normal development being restored only after the new stems and branches became well established. The extremities of the original bent-over trunks usually atrophied and decayed away, leaving the trees with a sort of "arm and elbow" appearance (Fig. 4). But occasionally the original trunk tip took root at its point of contact with the ground. When this happened, the tree functioned thereafter with two sets of roots (Fig. 6). Observations of growth rings on trail trees showed that they

[1] The latter method is reported to be in use at the present time among the jungle natives of the Philippine Islands. Personal communication from Dr. Fay-Cooper Cole, University of Chicago.

FIG. 3. COMMON METHOD OF ESTABLISHING TRAIL TREE MARKERS

a. SAPLING, YOUNG ENOUGH TO WITHSTAND ACUTE BENDING NEAR BASE. *b.* TREE BENT AND HELD IN POSITION BY HITCHING WITH RAWHIDE. *c.* LATER, SECONDARY STEMS APPEAR ALONG THE BENT TRUNK, REPLACING THE ORIGINAL BRANCHING STRUCTURE. *d.* SEVERAL SEASONS LATER, THE NEW BRANCHING STRUCTURE HAS MADE CONSIDERABLE PROGRESS, WHILE THE ORIGINAL, PROSTRATED BRANCHES HAVE DISINTEGRATED. *e.* YEARS LATER, THAT PORTION OF THE TREE BEYOND THE POINTS OF EMERGENCE OF THE SECONDARY STEMS HAS ENTIRELY ATROPHIED AND DECAYED AWAY.

were severely stunted by such treatment. Their sizes, therefore, are not as great as normal trees of the same ages.

The question naturally arose as to whether or not the Indians used any kind of selection in their use of trees for trail markers. The wide variation in tree types constituting trail markers indicates that any apparent selection was purely coincidental. The Indians necessarily had to limit their selections of markers to whatever types of trees happened to be growing along the proposed route. Some species of trees are more easily bent at sharp angles without breaking than are others. Deciduous trees, such as oaks, elms, hickories and maples, are best suited for this purpose. Hence, the custom of using tree markers was limited largely to regions wherein the dominant forest growth at that time consisted of such broad-leaved trees. Bent tree markers seem never to have been used in localities of high altitude or latitude where the less supple coniferous trees are dominant. On the other hand, tree markers were used quite widely in many parts of the Mississippi Valley, the lower Great Lakes region and eastward, where deciduous timber constituted the dominant forest growth.

Even a deciduous tree, however, must be quite young in order to permit its main stem to be bent at a sharp angle

near the ground without being broken. Occasionally no tree young enough for this purpose happened to be growing in a spot where a trail marker was desired. In such a case the Indians resorted to the bending of the lowermost branch of an older tree (Fig. 8). The effect upon that particular branch was similar to that upon the main stem of a young sapling—the branch put forth new secondary branches which extended upward at an odd angle in relation to the main branch.

It is easy to see that an Indian trail, extending across country for many miles, might contain markers consisting of various species of trees, as well as of trees bent in either manner. The species of tree was of no concern whatever as long as it was suitable for bending. The manner of bending, as has been seen, was dependent upon the age of the tree, the materials at hand, and the custom or ingenuity of the individual performing the work. Of extreme importance, however, was the direction of the bend. The trees were always bent so that they pointed parallel to the direction of the trail to be followed.

Although remaining tree markers are relatively few and far between, it appears that they were originally spaced at varying intervals, depending upon the density of the forest and other conditions encountered along the proposed route. Sometimes they were only a few hundred feet apart. At other times they may have been separated by distances as great as a half mile. North of Chicago there is a marked trail extending from the shore of Lake Michigan to the site of a former Indian village in the Skokie Valley five miles away. This trail crosses the central part of the town of Highland Park, Illinois. Thirty years ago there were eleven markers along this

FIG. 4. "ARM AND ELBOW" ASPECT

SUBSEQUENT GROWTH, WITH THE ISSUANCE OF A SINGLE SECONDARY STEM, CAUSES THE MARKERS TO ASSUME THIS SORT OF APPEARANCE. THIS ONE STANDS NEAR FOX LAKE, ILLINOIS.

FIG. 5. KNOB CLEARLY SEEN

THE SMALL KNOB, MARKING THE POINT OF ATROPHY OF THE ORIGINAL TRUNK TIP IS CLEARLY SEEN IN THIS MARKER. TREE SURGERY HAS AIDED IN PROLONGING THE TREE'S LIFE.

FIG. 6. THIS MARKER NOW FUNCTIONS WITH TWO SETS OF ROOTS
THE TREE BECAME ROOTED AT ITS POINT OF SECONDARY CONTACT WITH THE GROUND. IT IS ONE OF A LINE OF SEVERAL TREES MARKING A FORMER TRAIL THROUGH HIGHLAND PARK, ILLINOIS.

FIG. 7. A SORT OF MONUMENT IN A PUBLIC PARK
WHEN PROPERTY IMPROVEMENT NECESSITATED THE REMOVAL OF THIS TRAIL MARKER, THE LOCAL D. A. R. CHAPTER RELOCATED IT AS IT APPEARS HERE AT EVANSTON, ILLINOIS.

route—to-day only seven remain. In this trail the closest markers are less than two hundred feet apart, and the farthest more than a half mile. Undoubtedly, they were originally spaced at relatively close intervals. Construction of buildings and civic development have since taken their toll from the original line of markers.

In the course of the study, attempts were made to locate additional unknown markers by plotting known ones on the maps and extending their bearings as indicated by compass readings. In several cases, additional markers were thus located. In other instances the sites of former markers were confirmed through interviews with old settlers and property owners.

Local interest in these trail markers has recently inspired many property owners with the desire to preserve as long as possible these living monuments

FIG. 8. LOWER BRANCH BENT
WHEN NO CONVENIENT SAPLING HAPPENED TO BE GROWING AT A LOCATION WHERE A TRAIL MARKER WAS REQUIRED, THE INDIANS RESORTED TO THE BENDING OF A LOWER BRANCH ON A LARGER TREE.

FIG. 9. LOCATED ON GOLF COURSE
HAVING ONCE STOOD IN THE MIDST OF A THICK WOODS, THIS MARKER IS ONE OF A FEW TREES ALLOWED TO REMAIN WHEN THE LAND WAS CLEARED FOR AN EXCLUSIVE SUBURBAN GOLF COURSE.

on their lands. Consequently, timely tree surgery has prolonged the lives of many of these old trees. In a few instances, clubs and civic organizations have placed bronze markers on, or near, such trees (Fig. 7).

Among the many crooked trees encountered, only a few are Indian trail markers. The casual observer often experiences difficulty in distinguishing between accidentally deformed trees and those which were purposely bent by the Indians. Deformities may occur in many ways. A large tree may fall upon a sapling, pinning it down for a sufficient length of time to establish a permanent bend. Lightning may split a trunk, causing one portion to fall or lean in such a way as to resemble an Indian marker. Wind, sleet, snow or depredations by animals may cause accidental deformities in trees. However, such injuries leave scars which are apparent to

the careful observer, and these may serve in distinguishing such trees from Indian trail markers.

Observations have shown that the fall of a large tree upon a young one will cause the latter to bend in a wide arch beginning from the tree base. Indian trail markers are never bent from the base. The bend is usually from one to five feet above the ground and forms a rather sharp angle. Also, unless trail trees have been subsequently injured, they do not bear scars other than the knob left by the decay of the original trunk tip. Such knobs might be called remnant-scars as compared to injury-scars. In any event, a line of similarly bent trees, spaced at intervals, and all directed parallel toward or away from each other, would preclude the possibility of accidental deformity.

There is a popular notion that the Indians possessed an infallible sense of direction, and consequently required no trail markers. Even though it be granted that the savage possessed a keener sense of direction than his white brother—whether it were a natural instinct or the result of practice in the ability to read and interpret natural phenomena—it does not necessarily follow that a mere knowledge of the right direction is the only information needed to travel readily from place to place. There are numerous reasons for marking a trail, even though the general direction to be traveled is known. A direct route from one locality to another might be obstructed by natural barriers such as unusual elevations or depressions, non-fordable bodies of water, treacherous swamps or dense thickets of thorny underbrush. To facilitate travel, a marked detour might be advisable. Then, too, a hunting party in search of game might wish its route to be followed by the squaws who could collect the game and bring it back to camp. Scouts

FIG. 10. SUBSEQUENT GROWTH AFTER BENDING

THAT PORTION OF THE TREE IN THE NEAREST DIRECT LINE WITH THE ROOTS HAS BEEN FAVORED. SUCH GROWTH IS COMMON TO MARKERS WHICH HAVE PRODUCED MORE THAN ONE SECONDARY STEM.

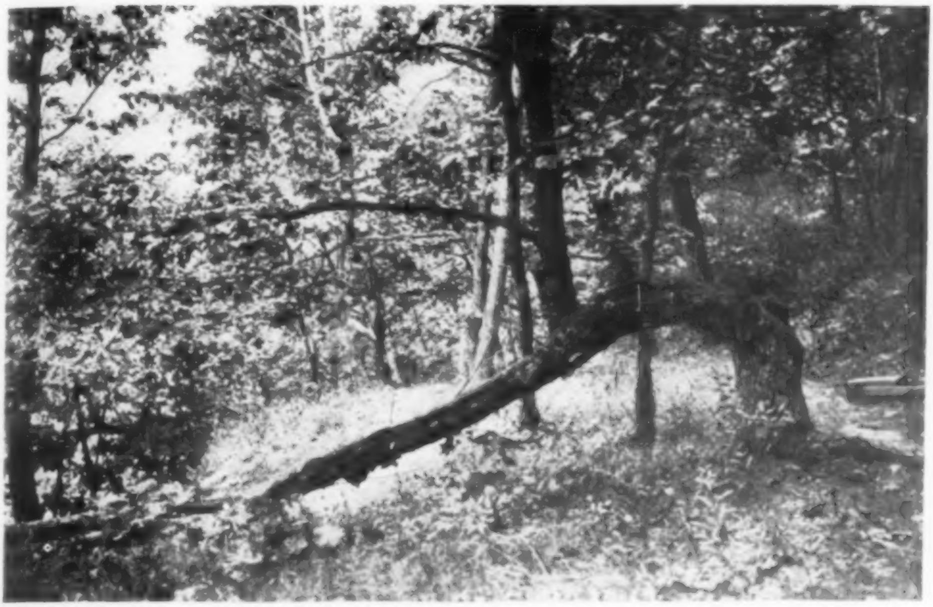


FIG. 11. MARKER NEAR WISCONSIN RIVER AT WISCONSIN DELLS
THIS IS ONE OF TWO SUCH TREES STILL STANDING IN THAT LOCALITY.

sent out in advance of a raiding party might wish to mark their trail so that the warriors might follow them into unfamiliar territory. Various other reasons may suggest themselves. However, long-established and important routes of travel probably were not marked, inasmuch as the paths themselves, worn well into the ground, were readily followed. The trail markers were undoubtedly placed along routes which were temporary or less frequently used than the main thoroughfares of Indian travel, or along new routes which later became heavily traveled.

Only for the past hundred years has the Mississippi Valley, in its entirety, been the undisputed home of the white man. During the preceding centuries it was, in turn, the domain of some of the strongest tribes of the North American continent. Much of the Indian history of those early days must, of necessity, remain forever unknown; but a portion of that history is simply told by the old trail markers which may still be found growing in numerous localities.

Because of the longevity of trees, many of these old trail markers, now gnarled with age, still stand as living reminders of the time when mid-western America was a favorite hunting ground of the savage red man. A few more years, perhaps, and the last of them shall be gone forever—as are the Indians who bent them.

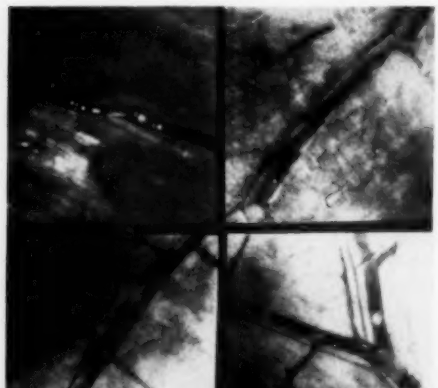
AEROEMBOLISM: A MEDICAL PROBLEM IN AVIATION AT HIGH ALTITUDE

By Dr. W. RANDOLPH LOVELACE, Dr. WALTER M. BOOTHBY and Dr. OTIS O. BENSON, Jr.

THE MAYO CLINIC, ROCHESTER, MINNESOTA

ALMOST every day new accounts are to be found of airplanes that excel in speed or will reach altitudes unthought of a year ago. The word substratosphere is in the common vocabulary and we concede the aeronautic and engineering sciences almost no limit of accomplishment.

Scientific interest in the physiologic problems of flight has been rather sporadic throughout the history of aviation.



Courtesy of H. G. Armstrong

NITROGEN BUBBLES IN VEINS OF EXPERIMENTAL ANIMALS, PRODUCED BY RAPID ASCENT TO HIGH ALTITUDES.

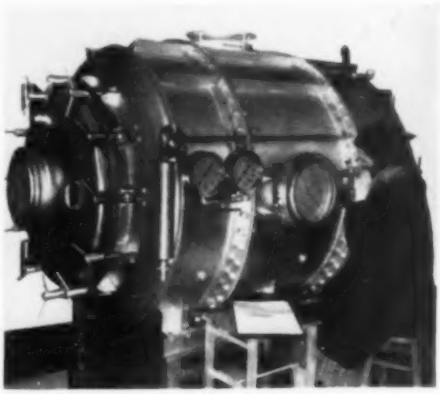
The universal and time-worn method of trial and error has usually been employed, and only after some major misadventure has the problem gone to the laboratory for solution. Paul Bert was stimulated, in part, in his experimental studies of the effects of low barometric pressure on the body by the unfortunate and bizarre stories related by the balloonists of that time. Trained scientists and laboratories were not available during the past war until appalling tragedies in flying commands made studies of flying personnel and the physiologic problems involved of paramount necessity. Likewise, commercial air lines paid little attention to the physiologic problems of flight until frequently recurring disasters forced them to seek aid in solving the physiologic problems of the human machine in the air.

The constant achievements of the aeronautic and mechanical engineers have created and are creating new physiologic problems. A race is in progress between the engineers and the physiologists, with the engineers setting the pace. We are inclined to accuse them of building a machine to transport man but on the completion of the machine finding that man can not take full advantage of its performance and that he was not seriously enough considered during the building process. It is the great performance of present-day aircraft that creates abnormal environments for man; high speed, rapid climb, steep descent, centrifugal forces, long intervals of flight, high ceiling with its

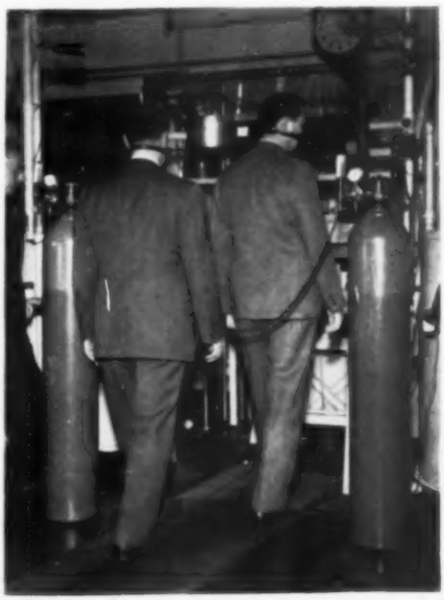
environmental changes such as cold, glare and low oxygen pressure, and finally, great changes in barometric pressure. It is the problem caused by the rapid decrease in barometric pressure in ascent to high altitudes that we wish to discuss in this paper.

Boycott and Haldane, in 1908, first mentioned the possibility that caisson disease (air embolism) might develop in aviators if too rapid an ascent was made. They based their opinion on the fact that the blood and tissues of the body are always fully saturated with atmospheric gases at sea level since the blood in the lungs is exposed to these gases and each is in solution according to its partial pressure. Nitrogen, which is physiologically inert, and hence not utilized, is taken up in physical solution by the blood in the lungs in relatively large amounts because of its high partial pressure (approximately 79 per cent. of an atmosphere) so that at sea level the nitrogen in the blood is in saturation equilibrium with the nitrogen in the alveolar air at a partial pressure of approximately 560 mm $[(760-47) \times 0.79]$.

Armstrong, working on physiologic problems of aviation, has demonstrated the occurrence of air emboli during experiments in a low pressure chamber and has called the condition aeroembolism; he defines it as a disease produced by a rapid decrease of barometric pressure below one atmosphere, such as may occur in airplane flights to high altitude. The disease is characterized by the formation of nitrogen bubbles in the body fluids and tissues and its causative factors are fundamentally the same as in the case of bends or air embolism in deep sea divers or caisson workers. If, in flight or in a low pressure chamber, the pressure is reduced from 760 mm to 150 mm, approximately equivalent to an altitude of 38,500 feet, the same effect would be produced as by surfacing a diver from an excess pressure of four (total of five) atmospheres after he had been at that depth long enough for his blood to be saturated with nitrogen at the increased pressure.



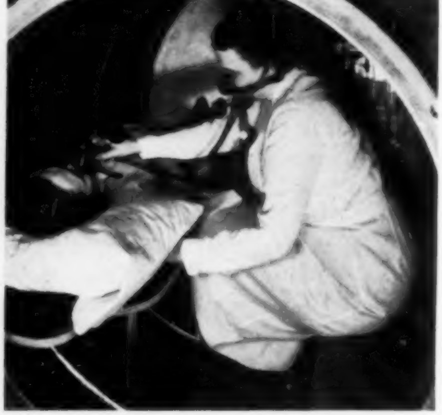
PRESSURE CHAMBER
WITH TECHNICIAN AT CONTROLS OBSERVING AND TALKING BY TELEPHONE TO SUBJECTS INSIDE.



EXERCISING ON TREADMILL
AT TWO MILES PER HOUR, WHILE BREATHING 100 PER CENT. OXYGEN WITH BOOTHBY, LOVELACE, BULBULIAN INHALATION APPARATUS.

ANALYZING ALVEOLAR AIR

METHOD OF OBTAINING AND COLLECTING SAMPLES TO CHECK AMOUNT OF OXYGEN REQUIRED PER MINUTE WHEN USING THE B. L. B. APPARATUS.



INSIDE THE CHAMBER

OBSERVATIONS BEING MADE BY THE TECHNICIAN ON A SUBJECT LYING DOWN; BOTH ARE OBTAINING OXYGEN BY USE OF THE INHALATION APPARATUS.

Whenever the atmospheric pressure is decreased, as during the ascent of an airplane, the partial pressure of nitrogen in the body fluids and tissues is obviously greater than that of the nitrogen in the air of the alveoli of the lung, and the tissues, therefore, are temporarily supersaturated. Consequently, in an effort to equalize the pressure, the nitrogen dissolved in the blood begins to be given off in the alveoli of the lungs and the nitrogen in the tissues begins to enter the blood stream. When the ascent or decrease in the barometric pressure is sufficiently slow that the nitrogen in the body can be eliminated and its concentration does not exceed somewhat less than double its normal saturation at the given altitude, nothing unusual will happen. However, when the concentration of nitrogen in the body attains, approaches or exceeds more than double its normal saturation value at any altitude-pressure, the nitrogen gas will tend to come out of solution and form bubbles. It has been demonstrated that the bubbles are formed, not only in the blood but also in the tissues and other body fluids. The tissues which have the highest fat content are the most favorable site for bubble formation since nitrogen is more soluble in fats and oils than in water, as found by Vernon in 1907 and confirmed by Campbell and Hill in 1931.

The normal nitrogen gas content of the body (not to be confused with organic nitrogenous compounds) is usually estimated as being about 1,000 cc under normal conditions at one atmosphere's pressure; sea level. Burns gave the following figures for the nitrogen content of a man weighing about 155 pounds (70.3 kg): Total of 995 cc distributed in blood, 30 cc; fat, 530 cc; bone, 0 cc; residue, 435 cc. It has been shown that the blood and other body fluids contain about the same quantity of nitrogen as would water under similar conditions of temperature and pressure. However, on analysis it has been shown that bone marrow contains about 5 cc of nitrogen per 100 cc of tissue and the brain tissue contains 1 cc of nitrogen per 100 cc of tissue. The greater solubility of nitrogen in fatty tissues is of importance in the elimination of nitrogen from the

body and in the symptoms of air embolism.

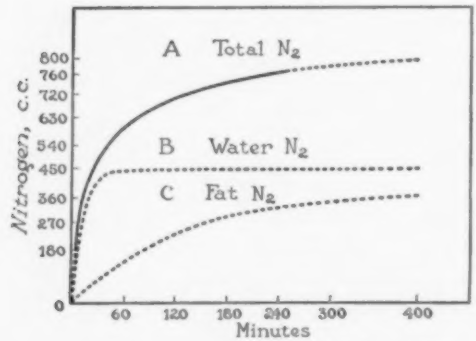
The symptoms of aeroembolism, just as the symptoms of caisson disease, depend primarily on the location and size of the nitrogen bubbles that are formed. These bubbles, when in the blood vessels in sufficient size and number, cause a mechanical obstruction of the blood flow and deprive the tissues of their normal blood supply with resultant sudden and severe anoxia. When the bubbles are small and numerous they may lodge in the capillaries of the lungs and, by their mechanical interference with the pulmonary blood flow, cause minute pulmonary emboli; this filtering, however, may protect the cerebral centers. The solubility of nitrogen in tissues with a high fat content and relatively poor blood supply, such as the spinal cord, makes this a frequent site for bubble formation with paralytic symptoms.

Armstrong has described the various symptoms of aeroembolism in the order of their occurrence as follows: pain about the joints which may be quite mild at the onset but soon becomes gnawing and boring in character, and finally becomes so painful that relief is sought; pruritus of the skin and eyelids and formication; abnormal thermal sensations of hot or cold; cutaneous erythema and often urticaria, and localized pain in the nerve trunks or neuritic pain in the peripheral nerves as a result of formation of bubbles in the myelin sheaths.

The small joints of the hands and wrists are most commonly involved, but shoulder, ankle, hip and other joints may be involved. Emboli to the lungs may plug up numerous small blood vessels, and finally a large region may be deprived of an adequate blood supply, the blood vessels of the lungs acting as a sieve to a certain extent. With bubbles (emboli) in the lungs there may, at first, be a burning pain and, as the condition progresses, the pain becomes finally sharp and stabbing. Edema, or fluid in the lungs, may develop, which results in paroxysms of coughing.

We have observed mild symptoms, suggesting the formation of small air emboli to occur at 18,000 feet, a pressure of one half atmosphere, after rather slow ascents, around 400 feet per minute. However, Armstrong and associates consider 30,000 feet to be the critical altitude after a rate of ascent of only 200 feet per minute. They describe the time of onset of symptoms as being somewhat variable, subject to individual variation, speed of ascent and final altitude or pressure reached. Symptoms may appear within five minutes after a sufficient altitude has been reached, or their onset may be delayed for several hours. Tunnel workers or "sand hogs," as they are called, often wear distinctive tags about their necks so that they may be identified and properly treated if severe bends develop hours after they emerge from the caissons. Obese individuals are possibly more susceptible than thin muscular individuals.

Pflüger early showed that nitrogen was removed from the blood of a dog when the animal breathed gas without nitrogen, and Paul Bert (1878) first tried the administration of pure oxygen to animals under excess pressure in order to prevent the development of caisson disease. However, the method generally employed in decompressing divers was the stage method as developed by J. S. Haldane. This consisted of bringing a diver to the surface by stages; the purpose of the stages or stoppages at various levels being to allow the excess nitrogen in the body to be given off and equilibrium to be nearly reached between the nitrogen of the inspired air and the tissues. This method was found to be fairly effective but very slow, and is



Courtesy of Behnke, A. R.

CHART OF NITROGEN ELIMINATION

SOLID LINE SHOWS NITROGEN ELIMINATION FROM A YOUNG, WELL-DEVELOPED MAN WEIGHING 60 KG WHEN PURE OXYGEN IS BREATHED. DOTTED LINES SHOW RATE OF ELIMINATION OF DISSOLVED NITROGEN IN MAN FROM WATER AND FAT RESPECTIVELY.

obviously too slow to be of value in aviation.

Hill (1912) and Bornstein (1913) demonstrated that, by breathing oxygen, nitrogen could be eliminated from the body. Recently, Campbell, and L. Hill and Behnke have contributed valuable quantitative data with reference to the total nitrogen in the body and its rate of elimination while breathing essentially 100 per cent. oxygen. They found that, with the subject at rest, 95 per cent. of the total nitrogen is eliminated in four hours, and approximately 99 per cent. in six hours. Although half the total nitrogen is eliminated in approximately forty minutes, it must be noted that at least eighty minutes are required for half the nitrogen to be eliminated from the fatty tissues.

The inhalation of 100 per cent. oxygen reduces the partial pressure of nitrogen in the inspired air to practically zero as the nitrogen in the lungs is quickly washed out. As a result, the nitrogen in the blood passing through the lungs diffuses into the alveoli and is expired, since gases always diffuse from a region of high pressure to one of lower pressure of that particular gas. In a few minutes most of the nitrogen in the blood will be eliminated. However, the blood in its passage through the tissue capillaries will take up additional nitrogen, carry it to the lungs, and there give it off. The tissues with a high fat content are commonly relatively avascular, and hence give up their nitrogen rather slowly and account for the long period of time required to free the body entirely of its nitrogen. Exercise while breathing oxygen in the decompression of divers was early advocated by Haldane and Priestley to accelerate the circulation and hasten the removal of nitrogen.

Our immediate interests and experimental efforts have been centered on perfecting a method or methods of rapid and effective nitrogen elimination. It is evident from the foregoing discussion that the inhalation of 100 per cent. oxygen is the most effective and practical method of eliminating the nitrogen by establishing a high diffusion pressure head from tissues to lungs. Exercise with its concomitant increase in the circulation rate while breathing oxygen offers the best method known at present to eliminate the store of nitrogen of the body in the shortest interval of time.

To date we have made 102 ascents to 30,000 feet, eighty ascents to 35,000 feet and thirty ascents to 40,000 feet in a low pressure chamber. The rates of ascent have varied from 350 feet a minute to 4,700 feet a minute. The subjects have remained at the peak altitude (35,000 feet) for as long as two hours and fifteen minutes, although it has been more usual to maintain the highest altitude from ten to thirty minutes.

Several of the slower ascents were made without preliminary nitrogen decompression in the earlier experiments, but all recent observations have been made after the subjects had breathed essentially 100 per cent. oxygen making

use of the B.L.B. inhalation apparatus both sitting at rest and exercising *in situ* or on a treadmill. The subjects have been supplied with oxygen in adequate amounts up to 33,000 feet while in the low pressure chamber to avoid the symptoms of anoxia and to maintain the low nitrogen pressure on the alveolar side of the pulmonary membrane; above this level even pure oxygen will not maintain a normal alveolar oxygen, and at 40,000 feet the subject has an average alveolar oxygen pressure of only 56 mm instead of the normal pressure of 100 mm at sea level.

We have considered symptoms such as "light-headedness," smarting or stinging of the conjunctiva, formication and fleeting joint pain as suggestive symptoms of air embolism. Aching pain in the extremities and joints, stabbing chest pain and incessant non-productive cough are believed to be quite pathognomonic, especially if they begin suddenly and become progessively more severe at the higher altitudes only to subside at lower altitudes. We have observed the symptoms enumerated, and on one occasion two subjects, who breathed pure oxygen for only twenty minutes at rest, ascended to 40,000 feet in fifty-four minutes (722 feet per minute). At this height one of them experienced severe aching pain in the right third and fourth interphalangeal joints and metacarpophalangeal joints. The other subject complained of a neuritic type of pain in his arm and found that exercise had to be stopped because of excessive fatigue. Immediate descent to 30,000 feet caused the symptoms to disappear except for weakness in the arm in the subject having the neuritic pain at the higher level. Even the "fatigue" of the arm subsided soon after the ground level was reached.

In another experiment a paroxysmal non-productive cough developed in one of the subjects at 40,000 feet after he had given an alveolar air sample. He had been insufficiently decompressed prior to the ascent. The non-productive cough persisted for about two hours after descent, and there was a generalized soreness of the entire chest for the next twenty-four hours.

Premonitory symptoms of air embolism have been observed as low as 20,000 feet after a rather slow ascent when no preliminary decompression was employed. These symptoms consisted of stinging of the conjunctiva, formication and abnormal cutaneous thermal sensations.

With the data discussed, but in the absence of more quantitative data, we are able to state that we have not observed symptoms of air embolism, in either rapid or slow ascents to altitudes as high as 40,000 feet, if 100 per cent. oxygen was breathed for forty-five minutes or longer at rest or if exercise, while breathing pure oxygen, was performed on the treadmill at a rate of two miles per hour for twenty minutes or longer. It must be stated here, however, that the time spent at the high altitudes prior to the onset of symptoms is a variable factor, and that it is well recognized in diving operations that some individuals are particularly susceptible and others refractory to the formation of air emboli. Quantitative studies on the rate of nitrogen elimination while breathing pure oxygen under varying conditions of exercise and the percentage of the nitrogen in the body that must be eliminated to prevent embolism should yet be fully ascertained. Such studies are in progress.

The treatment of air embolism, once it has occurred, is recompression. In the case of the diver it means return to an increased barometric pressure, while in that of the aviator it consists of descent to a lower altitude where the atmospheric pressure is greater. The increase in

pressure will result in a reduction of size of the nitrogen bubbles that are causing the trouble. Complete elimination of bubbles is, however, a slow process because the recompression reduces the size but does not remove them from the tissues and the blood. The bubble, in addition to its surface energy, reaches equilibrium with the gases in the surrounding media. Boycott, Damant and Haldane demonstrated bubbles in the blood stream of a goat two days after decompression, and in the spinal cord ten days after decompression. It has been found that 100 per cent. oxygen should be inhaled in addition to the recompression to allow the nitrogen of the bubbles to diffuse out completely, as demonstrated so well by Behnke and Willmon, who had the divers that participated in the salvage and rescue operations of the *U.S.S. Squalus* breathing pure oxygen by means of the B.L.B. inhalation (7) apparatus during recompression after rapid ascent.

The hazards of aeroembolism are especially important in military aviation because tactical considerations of high altitude flying necessitate a very rapid rate of ascent. For instance, the chief function of an interceptor-fighter airplane is to reach a high altitude as rapidly as possible on air raid alarm in order to engage in combat with the enemy before they can accomplish their mission, which may be bombing or observation. For tactical effectiveness against an enemy plane with a cruising speed of 300 miles per hour at 30,000 feet, an interceptor plane must be able to reach this altitude very quickly, since in ten minutes' time the enemy aircraft will be 50 miles nearer its objective. The pilots who are on call for these pursuit missions in time of war, if the intelligence net be far enough out (forty minutes), can rapidly eliminate the greatest proportion of their body nitrogen by breathing oxygen and exercising for twenty-five minutes. In the event of only ten minutes of advance intelligence, as may be the case in active aerial warfare, the squadron crew should come on duty twenty minutes before actually taking over and breathe pure oxygen while at the same time exercising by stationary running. They will thereby desaturate their bodies of nitrogen and make it safe to climb immediately into their planes and take full advantage of a rapid rate of climb.

Test pilots of the large airplane factories at the present time, no doubt, subject themselves to the dangers of aeroembolism in their tests of high performance airplanes. Proper facilities for preventing accidents of this nature should, of course, be provided.

Essentially 100 per cent. oxygen has been administered to more than 2,000 patients for as long as twenty-four hours with no evidence of ill effect. Helium-oxygen mixtures have been used with great success in decompressing divers in very deep diving operations, but the use of helium for this purpose in aviation offers no advantages, and might even complicate the procedure.

The use of pressure cabin airplanes is coming into vogue, and the pressurized suit has been used in several record altitude ascents by heavier than air machines. They can maintain any predetermined internal pressure, and hence insure an adequate partial pressure of oxygen and protect the occupants from marked changes in barometric pressure, a valuable consideration from the standpoint of the middle ear. However, as very high altitudes are reached, a marked pressure differential is established between the suit or cabin and the surrounding atmosphere. A failure of the cabin or leak in the suit means a sudden explosive decompression, the severity depending on the pressure differential,

with sudden oxygen want and, probably worse, the likelihood of severe aeroembolism. Partial nitrogen decompression prior to ascent in the pressure cabin or pressure suit would appear to be advisable if high altitudes are to be reached and a relatively high pressure differential is to be maintained.

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A NEW WORLD?

LOOKING at the facts immediately before our eyes, there is abundant reason to feel that 1940 may go down in history as one of its darkest pages. This is the year in which we have witnessed the fall of most of the democracies of Europe. It is the year in which we see Great Britain fighting heroically for her life. It is the year in which human freedom everywhere is in mortal danger. Yet if this remaining fortress of democracy across the sea holds out and eventually conquers, what has passed may turn out to be only an evil, tragic dream, that will be dissipated in the dawn of a better day.

For it is not impossible that history may record the most momentous happening in 1940 as having taken place in the laboratory rather than on the battlefield. I am thinking that the truly epoch-making event of the year may be man's first successful attempt to release atomic energy, through the isolation of Uranium 235.

The importance of this new discovery lies in the fact that a natural substance, existing in comparative abundance, has been found capable of releasing energy on an unbelievable scale. The isolation of that substance is an exceedingly difficult process, but—in laboratory quantities—it has now been accomplished. A single pound of Uranium 235, it is said, will provide the energy equivalent of three million pounds of gasoline or five million pounds of coal. The utilization of that energy, once the substance is available in commercial quantities, becomes a practical matter.

Scientists are hopeful that a method of isolating UR 235 in large quantities can be developed. I have learned from long experience to have more faith in the scientist than he has in himself. Experience and faith tell me that—given time, facilities and freedom to follow where imagination leads—the scientist will do all he hopes to do, and more.

What coming generations may be able to see with their own eyes and judge from their own experience is to-day almost beyond the scope of our imagination. With atomic power, people may be able to light, heat, ventilate and refrigerate their homes with ease and at trifling expense. Ships, railway trains, automobiles and airplanes may be fueled for life at the time they are built. Men may carry in their pockets personal radio telephones which will enable them to communicate throughout the world. A myriad of new products and services will become available to all. Many of the old hardships and deprivations—the sources of social and economic unrest—will disappear. A new society, dwelling in a new economy of abundance, will be born.

Is all this a dream? Yes, but it is the dream stuff of science, and our dreamers are the scientists who are opening new vistas for civilization. —*David Sarnoff.*

THE BIMILLENNIUM OF THE BIRTH OF AUGUSTUS CAESAR

AN ESTIMATE OF HIS WORK AND CHARACTER

By Dr. WALTER WOODBURN HYDE
PROFESSOR OF GREEK AND ANCIENT HISTORY, UNIVERSITY OF PENNSYLVANIA

THE year 1938 marked two great anniversaries, one important to us Americans, the other to world history. On June 21st we celebrated the birthday of a great democratic ideal, for on that day one hundred and fifty years ago New Hampshire cast the enabling vote for the ratification of our Constitution, at once the fountain-head of our liberties and the supreme law of our land. On September 23rd two thousand years ago Augustus Caesar, founder of the world's most important enpire—that of Rome, was born, an anniversary which was celebrated in most of the universities of the world wherever ancient history is taught. His advent meant not only much to the world of his day, but also to ours, since out of his creation have come the political ideas, traditions and largely the culture of our time; for the Roman Empire still lives in its language, literature, municipal system, imperial idea of church and state, and in many less obvious ways still influences our thought and life. It is fitting, therefore, that we review the career of its founder and glance at the world into which he was born and that which he left.

By his victory at Actium in 31 B.C., Octavian, the future Augustus, ended the century of revolution and civil strife at the close of the Roman Republic, and ushered in an era of prosperity and peace for the Mediterranean world which lasted two hundred years. The Roman world lay exhausted in the hands of one able and fortunate enough to remodel its fragments into an enduring state. It was indeed a great work to organize out of chaos and anarchy a splendid mechanism of orderly government which with modifications stood for centuries. In the words of Merivale, the historian of its first two centuries: "The establishment of the Roman Empire was after all the greatest political work that any human being ever wrought. The achievements of Alexander, of Caesar, of Charlemagne, of Napoleon are not to be compared with it for a moment." Haverfield, the historian of its westernmost province, Britain, has said: "No empire has left so great a name as Rome. None has so thoroughly conquered its barbarian conquerors and set so deep a mark on the memory of succeeding generations." Of its tragic passing none has spoken so feelingly as Professor J. S. Sheppard in his "Fall of Rome and Rise of New Nationalities"—though "fall" is misleading, since it involved no catastrophic governmental collapse, but merely a regrouping of its parts: "No event, perperhaps we should rather say no series of events, in the secular history of mankind, can equal in interest the fall of the Roman Empire. Our minds are overwhelmed by the grandeur of the image which the name of Rome evokes. Throughout all the mutations of human affairs and the vicissitudes of what men call Fortune *magni stat nominis umbra.* The giant shadow broods over the birth of European civilization and projects itself into the depths of an unknown future. As on Rome all ancient history converges, so from Rome all modern history begins." And Gibbon, author of its decline, more tersely spoke of its pas-

sing as "a revolution which will ever be remembered and is still felt by the nations of the world." And we should remember with Hodgkin, the historian of its barbarian invaders, that "when Rome ruled she was not only the greatest but practically the only Power of which the statesman and the philosopher took any cognizance."

Long before Caesar's assassination on the memorable Ides of March in 44 B.C. the Roman Republic had waned chiefly because of internal troubles caused by her conquests. Democracy in Rome really ended when she ceased to be a city-state, for in antiquity, largely because of the lack of easy communication and newspapers, democracy could only exist in small areas. Throughout the long era of expansion from the First Punic War to the end of the Third—264–146 B.C.—Rome had conquered most of the countries in which the main current of history had theretofore run its course, and had found herself a world state. Her great problem was how to administer so colossal an aggregation of peoples and lands with her inadequate machinery of Republican government. The Senate continued to rule because it alone knew how to rule. But soon after the fall of Carthage and Corinth in 146 B.C. its power was disputed and this lasted for over a century when all sorts of problems, political, social, economic and military, were raised but not answered. Wealth had come through conquest and its accompanying slavery and not through agriculture nor industry.

Beginning with the tribune Tiberius Gracchus in 133 B.C. a line of "supermen" arose, who in various ways tried to cure Rome's ills only to become in turn virtual dictators—Caius Gracchus, Marius, Drusus, Sulla, Pompey, Caesar, Antony and Octavian. In fact, the last century of the Republic marks its death-struggle and the birth of a new era. One of its most dangerous features, inaugurated by Marius, the savior of Rome against the Cimbri and Teutones (102–101 B.C.), was the turning of the old national militia into a voluntary professional army interested far more in its commander than in the state for spoils and so became a public menace. By Pompey's time he could boast that he needed only to stamp his foot and armed men would spring from the soil of Italy to do his bidding. Julius Caesar soon after the First Triumvirate (60 B.C.) engaged him in civil strife and, when successful, instituted far-reaching reforms in the Constitution, but his efforts only led to his assassination before he had completed his work, and Rome lost the "one original genius of her history."

Julius Caesar has indeed left an indelible stamp on history and "did bestride the narrow world like a Colossus." Schoolboys still puzzle over his commentaries on the Gallic War—a conquest among the greatest in their results, whatever we may think of the morality of an undertaking which caused the death of perhaps a million human beings and the banishing of liberty from a huge area; historians still study his career and generals his battles; and kings emulate his example, his very name their proudest title—Kaiser or Czar. But despite all he did perhaps his best epitaph is this of Professor Adcock: "Caesar had done much for the state in his reforms, but he did no greater service than by his death." Still his assassination was no stroke for freedom as the liberators had imagined, but one of the most futile acts of antiquity—for it struck a wise ruler and not the monarchy which was inevitable. His death caused the Roman world untold suffering for nearly fourteen years—proscriptions, civil war, the mad rule of Antony and despair, until Octavian, a man of far lesser mould, got rid of his rival Antony and restored and improved upon the system Caesar had inaugurated.

Only confusion followed the act. Caesar had made no provision for a successor and the conspirators no plans to take over the government or how to deal with Caesar's lieutenants, Lepidus, his master-of-horse, or Antony, the surviving consul. Cicero, who favored the conspirators, since his whole policy was to save the Republic, in a private letter said in slaying Caesar they showed the political sagacity of babies. They soon found their act met only ominous silence when Lepidus and his troops seized the Forum and Antony seized the papers and money of Caesar, and they soon took refuge on the Capitol. They had learned too late that though Caesar was dead his party lived on in his veterans and the mob now led by Antony, a past-master of political chicanery. He at once took advantage of the crisis and used every device to appear as Caesar's successor. He soon convened the senate, a majority of whose members favored the liberators, but, induced by Cicero, it voted a general amnesty and at the same time the ratification of Caesar's acts and his public funeral. Antony mounted the *Rostra* and delivered a stirring eulogy over the dictator's body, his violent rhetoric and display of Caesar's toga rent with dagger thrusts so inflaming the populace that they forthwith burned Caesar's corpse in the Forum and fired the liberators' houses. Cleopatra and her son Caesarion by Caesar left the city for Alexandria, where we shall meet them again; and soon the arch-conspirators, Marcus Brutus and Cassius, hurried east to the provinces assigned to them by Caesar—Macedonia and Syria respectively—to collect men and treasure for the inevitable struggle with Antony.

Two months after Caesar's death Antony found a redoubtable rival to his plans in the person of the dictator's grand-nephew, Caius Octavius, whom in his will Caesar had adopted and made heir of three-fourths of his estate. He was now a youth of eighteen, studying with his boyhood friend Agrippa in Epirus and there awaiting Caesar's arrival to accompany him on his proposed Parthian expedition. By the end of March he had learned of the murder and at once, despite the warnings of friends, crossed the Adriatic, and by the beginning of May reached Rome, where he demanded of Antony his uncle's property with which to pay the latter's legacies, and also declared his intention to avenge his death. But the latter, who had already dissipated much of the money he had received from Caesar's widow together with the public treasure which he had seized from the temple of Ops, refused and so began the long enmity, which with short intervals of outward friendship filled the pages of Roman history till Antony's death. Cicero now supported Octavius and denounced Antony in his savage "Philippics" until he drove him into Cisalpine Gaul. With the money he could raise by selling Caesar's real estate and contributions from friends and relatives the ambitious youth paid off Caesar's legacies and so gained immediate popularity.

Octavius now even made advances to the liberator party, and no one can withhold from him admiration for the adroitness with which he went on with his purpose. Supported by two legions which had come over to him, he induced the senate to name him praetor at the close of 44 B.C. and send him with the consuls for the next year to attack Antony, who was besieging Decimus Brutus in Mutina, since the latter refused to surrender to Antony the province of Cisalpine Gaul already assigned to him by Caesar. The consuls raised the siege, but were slain in battle before the walls, and Antony fled over the Alps in April, 43 B.C., where he was soon followed by Lepidus. Cicero, now suspicious of Octavius' motives, induced the senate to keep him from acquiring further

power. Nothing daunted, Octavius with the troops of the slain consuls marched on Rome—from which Cicero retired—and forced his election as consul. It was now also that he was formally adopted into the Julian *gens* by a *lex curiata* and that he added his uncle's name to his own—Caius Julius Caesar Octavianus. His first act as consul was to get the assassins condemned *in absentia,* and then he hurried north to meet the troops of Antony and Lepidus, now returning over the Alps.

Instead of a clash, however, the three leaders met near Bononia, and laid plans for their future aggrandizement. They got the senate to name them *Triumviri reipublicae constituendae* with dictatorial powers for five years *i.e.*, to restore the state. This—the Second Triumvirate—therefore was a different coalition than the preceding one formed in 60 B.C. by Caesar, Pompey and Crassus, for while that was merely a private political ring formed by Rome's then three most powerful men to further their personal ends, this had official sanction. At Bononia they also planned to attack Brutus and Cassius in Macedonia and cemented their union by blood, the terrible proscription of November and December, 43 B.C., one with hardly a parallel in ancient history. Among the chief victims of the butchery was Cicero, whose death Antony demanded and Octavian allowed. His dissevered head was exhibited on the *Rostra* where Fulvia, Antony's brutal wife, gazed upon it with joy and pierced the orator's tongue with a golden bodkin. The scenes which had accompanied Sulla's return to power forty years before were now reenacted, when 130 senators, 2,000 knights and many commoners were slain before opposition was crushed. The three also divided the western provinces among themselves, Octavian to have Sicily, Sardinia and Africa, Lepidus Spain and Narbonese Gaul, and Antony the rest.

Antony and Octavian now crossed the Adriatic and defeated the liberators in the two battles of Philippi in Macedonia in 42 B.C. where a century later Paul first preached in Europe the gentle gospel of Jesus. The Republic was now doomed and Brutus and Cassius committed suicide during the battles. Now the Roman world was again divided on a grander scale, for Octavian took most of the Latin West and Antony the Greek East, Lepidus being reduced only to one province, Africa, the ancient territory of Carthage. Octavian returned to Italy to restore order and distribute promised lands to his veterans. It was then that he confiscated the lands of eighteen communities, among which were the farms of the fathers of three poets who later graced his court—Vergil, Horace and Propertius. But war soon broke out between Antony and Octavian, instigated by Fulvia, the chief incident of which was the besieging of Lucius, Antony's brother, in Perusia and its capture in 40 B.C. by famine when three hundred of its defenders are alleged to have been condemned by the victor during the futile plundering of that ancient Etruscan town. But Fulvia's death the same year made a reconciliation possible between the rivals, cemented by Antony marrying Octavian's beautiful sister Octavia, a harbinger, as was thought, of a lasting peace between them.

The years which preceded the final decision between the rivals were wasted by Antony in the East in fruitless campaigns against the Parthians and in his fatal romance with Cleopatra, the Egyptian queen. After Philippi he had proceeded to Greece and Asia Minor to complete the subjection of some of the eastern provinces. In the year 41 B.C. he had summoned certain client kings and princes to Tarsus in Cilicia to answer for their helping the liberators. Among them was the lovely queen, now twenty-seven and in the bloom of her

beauty, her advent marking the beginning of Antony's downfall. She came, her only defense against her accuser being her personal charm. She ascended the Cydnus in a gilded barge with sails of purple silk and oars of silver; beneath rich awnings the lovely queen reclined dressed as Aphrodite among her attendant Nereids and Loves. Antony succumbed to her beauty and talents, forgetful of country or honor, and the two spent nights and days in banquets and revelries, she amusing him by appearing as Aphrodite or Isis, and he impersonating the wine-god Dionysus or Osiris. Unchastened she led her accuser back to Alexandria, where, during the winter of 41 to 40 B.C., he forgot all duty.

It was when he was recalled to Italy by the Perusian War, which, however, had ended before his arrival, and after Fulvia's death, that he, for a time forgetting Cleopatra, became reconciled with Octavian, late in 40 B.C. marrying his sister. On his return to Asia the next year, he began his attempts to subdue the Parthians and spent some time in Athens with Octavia as a model husband, though his extravagant behavior there, especially by assuming the attributes of Dionysus, overrode Roman sensibilities. In 37 B.C. he returned to Italy for the last time to renew the Triumvirate, and, on his return once more to the East, he sent Octavia back to her brother and resumed his relations with Cleopatra, soon thereafter formally marrying her at Antioch, even though Octavia was not yet divorced. By this act, he publicly renounced all frendship with his rival.

Reports of Antony's un-Roman acts and especially his ill-treatment of Octavia, together with alarm at Cleopatra's rumored intention to form with him a Graeco-Oriental state, aroused indignation at Rome and soon the climax came. The Triumvirate ended in 32 B.C., and the senate was functioning once more. Octavian, at last ready to crush his rival, having received an oath of fealty from the senate and the western provinces and having published Antony's will—or a forgery of it—in which he disposed of the eastern provinces to the Egyptian throne, easily induced the senate to declare war on Cleopatra, thus avoiding the name of a civil war with Antony. The latter now divorced Octavia, who, however, proved herself one of the noblest of Roman matrons, for instead of resenting his insults she, after Antony's death, reared his children by both Fulvia and Cleopatra along with her own down to her death in 11 B.C.

Finally, on September 2, 31 B.C., the West again faced the East as it had done already at Philippi and Pharsalia, this time in the greatly overrated sea-fight off Actium on the west coast of Greece, hardly a battle at all, as it was attended by the treason and early flight of the chief combatant. Here Agrippa blockaded Antony's fleet in the harbor, though it outnumbered his own two to one, and cut off the land army from supplies. In the midst of the ensuing battle Cleopatra's fleet of sixty galleys, posted in the rear and carrying Egyptian treasure, sailed away for Egypt, and a little later Antony, seeing only defeat, followed, abandoning his fleet and army. But the tradition that the queen betrayed him and then received him on board her flagship after he had left no commands for his officers seems to be a fiction circulated by the victor's party, for Antony's version has never been told. His army surrendered without a blow and was forgiven by Octavian, who thus exhibited his first example of humanity in the long duel now ended.

Antony, now a rebel and fugitive, soon reached Egypt, where the last act of the tragedy was played. Knowing that Octavian would follow him, even as Caesar after Pharsalia had followed Pompey,

Antony tried to raise troops against him. Octavian, after spending the winter of 31–30 B.C. in settling the eastern provinces so badly neglected by Antony, reached Egypt early in 30 B.C. and besieged the queen and her lover in Alexandria. Seeing the desperate fortunes of Antony, Cleopatra negotiated with Octavian for his death, and entering her mausoleum caused the report of her own suicide to reach Antony who, unwilling to survive her, stabbed himself, insisting on being drawn up into the mausoleum by a rope, where he perished in her arms. The queen, after vainly attempting to move the passion of Octavian, as long before she had moved that of Caesar, took poison rather than live to grace the conqueror's triumph, and thus, at thirty-eight, ended the three centuries of the Greek rule of the Ptolemies over the land of the Pharaohs. Egypt, because of its importance as a granary, was kept from partisan leaders and ruled directly by Octavian as a private domain through a prefect. Other rivals there—including Caesarion—whom in 42 B.C. the triumvirs had allowed to receive the title of King of Egypt and who in 34 B.C. had been called King of Kings by Antony—were slain and finally the Roman state had a single master. Octavian, the last of the long line of supermen who had struggled for mastery, had won.

It was to the best interests of Rome that Antony, a curious mixture of sentimentality and cruelty, personally attractive but without positive virtues, should have lost to his colder rival. Legend has laid his failure to infatuation for a beautiful woman who is still a kind of enigma, since her coin-portraits do not bear out the tradition of her loveliness. But the truth seems different. His armies left him, their Roman spirit outraged when they learned that he intended to dismember the Roman state and with her found an empire with Alexandria as its capital. The legend circulated by Plutarch, who made the death-scenes of the "inimitable lovers" immortal in literature, came from Octavian's party. The truth is Cleopatra hoped to rebuild her crumbling fortunes through Antony, the best general of his time, but chose the wrong man. When she found Octavian would not be so used, suicide alone was left for this mistress of luxury and pleasure. On Antony we quote from a recent book by Professor Glover: "he might well be forgotten had not Plutarch written of him and Cleopatra and had not Shakespeare read Plutarch in English and written a play, . . . and all the way Shakespeare follows Plutarch, only (as Heine wrote) adding genius. To that play too the reader will turn and will understand why Augustus and not Antony ruled the world. Antony in truth belongs to literature far more than to history."

Octavian had made good his claim to Caesar's heirship. The Roman state, now weary of war, regarded him as a savior and creator of a new era—the Augustan Age. He reached Rome in 29 B.C., when his brother consul offered sacrifices for his safe arrival, an unprecedented honor. In August he celebrated his triple triumph for victories in Illyria, Greece and Egypt. On the first day Gallic and Illyric captives marched; on the second the beaks of Antony's ships were displayed with Asiatic princes, once his allies, bound with golden chains; and on the third Cleopatra's twins by Antony, now eleven years old and so too young to feel their disgrace, marched amid the Egyptian spoils and the effigy of their mother borne on a litter. But now, as in Caesar's quadruple triumph celebrated seventeen years before, no Roman was led captive. Octavian now was undisputed master of Rome; regarded by Greeks and Orientals as a God to whom temples of *Rome and Augustus* were later erected, an imperial cult kept

up as a focus of patriotism; ruling in Egypt as the successor of the Ptolemies, as these had been of the Pharaohs; and commander-in-chief of fifty legions. The ceremony ended with the dedication of the temple of *divus Julius,* his uncle, and the closing of that of Janus in the Forum—the third time only in the martial history of Rome as a symbol of "the immense majesty of that Roman peace," as the Elder Pliny called it.

Octavian now, to quote his own words, was "master of all things" and Rome looked to him, the victor, to rebuild the war-torn state into a constitutional government such as had not existed since Caesar crossed the Rubicon twenty years before. He found himself faced with the same problems which had faced his uncle—what sort of government he should institute and how he could fit one-man rule into it without offence to Roman sensibilities. To solve it he had little of the splendid genius of Caesar, "the foremost man of all the world," neither his patrician outlook as the descendant of gods and heroes nor his willingness to forget the past and build anew. To be sure, Caesar had lived too short a time after his civil war with Pompey was over to show just what style of rule he intended, further than concentrating all executive power in his own person, and not sharing it with the old oligarchy—the senate. Octavian possessed very different qualities which, however, were to win where genius failed—caution, patience to let time shape his course, perseverance and, above all, a sincere love of Rome's past. With such qualities he could not follow his uncle into abruptly breaking with tradition and, basing his rule on the army, blend Italian citizens with provincials, and let Italy lose her historical predominance, and so inaugurate a new and un-Roman régime.

Every one at Rome knew that monarchy was the only solution of the Republic's ills—those of a state long harassed by factions and civil wars, economic decay, lack of representative government, and withal based on slavery. During the last century mob-rule at times had turned the tribuneship into a dictatorship, and dangers on the frontiers had given undue authority to provincial governors over armies; such experiences had made Rome ready for a monarch—that had already been fulfilled in Caesar—but not for a king or dictator. Octavian knew that his uncle's fate was largely due to his contempt for Republican institutions and especially to his flouting of the senate; and he knew that the tradition of centuries of democratic rule, from the expulsion of the kings to Caesar's perpetual dictatorship (509–45 B.C.) could not be obliterated. To succeed, then, he could not follow Caesar's path which had led only to assassination, for Rome would support him only if he could conciliate tradition and harmonize the new state with ancient privileges and so preserve the old shell. His struggle with Antony, as Caesar's with Pompey, had shown that the senate was no longer the real issue, for it had interfered with neither, and on his return to Italy was in the same position it had been in back in 44 B.C., unable to recover its prestige or bring order and peace. Therefore it mattered little who should replace it in power, if only that man could restore the ancient unity. Thus he felt that he had no choice except to rebuild and not to destroy the ancient fabric, to cloak his personal rule under Republican forms, since a literal restoration of the past was impossible.

The task before him was indeed immense, and he performed it only gradually, for to conceive on the grand scale and to execute quickly were foreign to his cautious nature. But his final solution of the problem places him securely in the short list of the world's great statesmen. He must restore peace and prosperity in

Italy and the provinces after the ravages of a century of civil strife; lift the state out of political and economic chaos; regulate the frontiers and, for security's sake, extend them beyond the Alps to the Rhine and Danube; put down piracy and brigandage and relieve Rome from further fear of invasion and revolution; abolish abuses and institute beneficial laws; repair roads and cultivate waste-lands; patronize literature and art and start a program of religious and moral reform; conciliate a senate still possessed of powers accorded it by Sulla, and, above all, keep the affections of a people yet clinging to ideas of popular rule. He lived to do all this and more, and, in a word, became the "architect" of a new order—the Roman Empire.

Finally, in January, 27 B.C., at the beginning of his seventh consulship, he was ready to go before the senate to settle its status and his own in the administration of the future state. He there laid down all the extraordinary powers it had conferred on him in the last few years and declared "the Republic was restored." Thus he surrendered the *imperium* over all armies, provinces and revenues, and all privileges not consonant with the ancient Republican office of counsel, which alone he retained. Two weeks later, January 13, a date thereafter regarded as the birthday of the Empire, the subservient senate voted him back the more essential of his former powers for ten years, proconsular *imperium* over three provinces where armies were still needed—Syria, Spain and Gaul—and reconfirmed his personal rule over Egypt, power which again placed him above all provincial governors, the beginning of the famous "Dyarchy" or "joint rule" of himself and the senate, though there was no question of his predominance in the arrangement. Thus the old military problem of army control, which had injured Rome ever since the time of Marius, was solved, and Octavian became commander-in-chief of all armies with the right of levying troops, an office theretofore only enjoyed by generals in the field. His tribunician power also gave him the right to convene the assemblies as that of consul did the senate, and to veto all legislation both there and in the senate, and he found himself the supreme ruler of the state.

It was at this time that he also received the civic crown to hang over his private doorway in recognition of his having saved the state, and the cognomen Augustus, by which he is best known to history. This title implied no definite powers, but was merely expressive of his almost divine character, for it was the first time it had been conferred on a living man, a title like our "majesty" or "by grace of God." The senate also voted to change *Sextilis*, the sixth month of the ancient Roman calendar, to *Augustus*, as before it had changed *Quintilis* to *Julius*—names which we still use. The title *imperator*, already conferred on him by army and senate after his victory at Mutina in 43, now became his permanent praenomen connoting "commander-in-chief," as well as a title of honor. In the East, where his power was based frankly on the military, it meant more than in the West, where that basis was not emphasized. But he received and asked for no title offensive to Roman feeling, neither "king" which Caesar had coveted, nor "dictator," which he had accepted as a permanent title, though theretofore connoting only a temporary office in crises, nor "censor," which his uncle had taken. He had learned from Caesar's fate the art of holding supreme power without invidious titles, for he had sensed that an undisguised autocracy would only shock Roman sentiment.

Down to 23 B.C. his power at home rested on the annual consulship and tribunician power and abroad on the proconsular *imperium*. In June of that

year the Principate, as we still call the new constitution, received its final form. For now he laid down the consulship which he had shared annually with a colleague since 31 B.C. contrary to all precedent, but retained the *imperium* granted him for ten years in 27 B.C., though it was not valid in Rome. Thus he lost precedence over other magistrates long enjoyed by consuls and the right of convening the senate or holding assemblies. However, the loss was soon made up to him by the senate, which the same year made his *imperium* equal to that of consuls in Rome, and the following year gave him equal rights with the consuls in convening the senate, and in 19 B.C., outward equality with them by allowing him twelve lictors and a seat between those of the consuls. The significance of the extension of tribunician power year by year for life is shown by his dating the years of his further rule by it. In 36 B.C. he had received the tribunes' inviolability, and in 30 B.C. the right to offer aid, and now enjoyed the permanent right to veto legislation. Thus his supremacy was based on two pillars of power—proconsular outside Italy and tribunician inside, which made him a virtual autocrat. But the senate, assembly and magistrates functioned, and soon public life again ran in the familiar channels, though the controlling authority was his, now exercised under constitutional forms with the sanction of senate and people. Thus the old Republic, or whatever of it was worth keeping, was restored under the leadership of the *princeps civitatis,* the first citizen of the state. If it be difficult to define such a curious state, perhaps we might follow the explanation of Lord Tweedsmuir, governor-general of Canada, who, in his recent (1937) biography of Augustus, says: "But it is simpler to look upon the result neither as monarchy nor as republic, but as a mixed constitution, a new thing."

Further decrees made his position even more definite. But, in deference to tradition, he held no new office which would have given him openly supreme power, but the gradual accumulation of various offices made his position, though indefinite, known. Thus, in 19 B.C., he was granted the censorship of law and morality; in 12 B.C., at the death of Lepidus, he took over his title of *Pontifex Maximus,* which made him head of the state religion; in A.D. 2 he received his greatest honor, for now, after over thirty years of rule, he became *pater patriae,* which marked the final reconciliation of the *princeps* and the old oligarchy. The last step of all came at his death, when Tiberius, long associated with him in office, became his successor.

Within its frontiers—the Atlantic, Sahara, Rhine, Danube and Euphrates—lay the Roman state as officially adopted by the senate 27–23 B.C. Gibbon introduces the story of its decline with these words: "In the second century of the Christian era the Empire of Rome comprehended the fairest part of the earth and the more civilized portions of mankind." Hodgkin has added: "Even now a monarch who should thus hold all the lands around the Mediterranean Sea . . . would be incomparably the strongest ruler of the world." It was truly a magnificent domain, including all the countries around the fringes of the Mediterranean in the three continents of Europe, Asia and Africa. Under Trajan in the early second century at its widest extent it extended from York (Eboracum) to Thebes and from Lisbon (Osilipo) to beyond the Tigris and contained a population at least one third of that of the corresponding areas in our day—the one time in history when civilized man of the West was under one rule, that of the Caesars. Beyond its borders to the limits of the earth were realms only reached in the imagination of an Alexander or a Caesar, into which

Augustus, lacking both the will to conquer and the dazzling generalship of Caesar, and wisely staying the restless advance of Rome toward universal dominion which had marked the closing centuries of the Republic, never ventured to enter. It was his own more moderate idea to center all in Italy from the Alps to Sicily as the heart of the vast organism, and to demand from it the soldiers to protect it, fearful lest further drain on Italy's soldiery might imperil its safety at the hands of the encircling provinces.

Historians, in praising Augustus' work and the stability of the empire which he founded, doubtless have exaggerated its greatness—apart, at least, from its unconscious mission of transmitting ancient culture to our time, both that which it received from the older nations which it absorbed and that which it gathered from its own mighty course. During the first two centuries of its life the machinery of government ran smoothly enough (even though Domitian at the close of the first for a time renounced the Dyarchy). Under the Antonines— A.D. 138 to 180—it reached its apex of prosperity, even if some of it was specious, an era which has evoked the encomia of all historians. In fact no ruler who has since sat on a European throne has reached the moral stature and Stoic adherence to the duties of high office attained by Marcus Aurelius, the finest spirit among the emperors.

Then came the appalling crisis of the third century when the emperors were the sport of the legions, a period introduced by Septimius Severus, whose absolutist ideas make him, in the words of Gibbon, "the chief author of the decline of Rome," and followed by the worst half century in the story not only of Rome but of Europe. Further, the process of disintegration ate into the very heart of the state, which offered the pitiful spectacle of a vast moribund organism torn politically and strangled economically by forces it could not master —anarchy and revolt, division and loss of half its territory, plague and famine, unheard-of taxation and external pressure of the barbarians. Finally, after the heroic endeavors of a Claudius and an Aurelian—whose abilities were worthy of a more fortunate era—the last of the "barrack" emperors, Diocletian, called by Ferrero "the last great man of antiquity," stayed the downward course. But thereafter the empire visioned by Augustus three centuries before was no more, for his restored state, "the Dominate," was an un-Roman absolutism, under which one was master and the many were slaves. The story of its last century after the division of the huge colossus into its eastern and western halves at the death of Theodosius in 395 is a Greek tragedy, its gradual ruin a preparation for a new order—the Middle Ages. For the western half rapidly collapsed till its last vestiges disappeared eighty-one years later, when German kingdoms had occupied all the western provinces; but the more fortunate eastern half ruled from Constantinople, to which Constantine had moved the capital in 330, while proclaiming itself inheritor and continuator of old Rome, lived on another millennium as an Oriental type of medieval state, the "Byzántine Empire" with few Roman features beyond Diocletian's government pattern, till all that was left of it, the capital city on the Bosphorus, long protected by the massive walls of Theodosius II, fell to the Turks in the fifteenth century. This was the last remnant of antiquity projected into modern times.

Nor is it difficult to find grave flaws in the vaunted greatness of the first two centuries. Its greatest defect was the absence of political liberty. Even under benevolent despots man can be happy, as under the good emperors of the second century, as both Gibbon and Momm-

sen have shown. But that happiness depended then as later on the character of one man, sometimes a madman such as Caligula and Domitian, again a monster such as Nero, Commodus or Caracalla, again a religious fanatic as the boy emperor Elagabal, or a sensualist such as Gallienus. Nor should we regard the imperial system even at its best as a monument to political sagacity as older writers did, but rather, in the words of a recent writer, as "one of the most monstrous of all historical examples of graft, corruption and inefficiency," to find the equal of which we are compelled to come down to some of the democracies of our time. Augustus at best only evolved a partially adequate system, for his work was a compromise. There was no approach to scientific government till Diocletian, and then the great days of Rome were gone. For his huge bureaucracy and exploitation of the provinces by ruinous taxation only increased the economic decay, and Rome, in the words of Goldwin Smith, had become merely "a tax-gathering and barbarian-fighting machine." This was one of the major factors along with Christianity which finally brought the fabric to ruin.

Two other defects were inherent in the system from the beginning. Chief of these was the fact that, like modern dictatorships, the state was built around a personality, for Augustus as master of the legions could thwart the senate at will. Augustus certainly overrated the ability of the two corner-stones of his edifice — *princeps* and senate — whose functioning depended on the harmonious cooperation of these two imperial powers, the willingness of the one and the self-restraint of the other. As soon as the senate proved itself incapable, or the emperor abused his power, the entire structure was certain to develope into a military despotism. As a recent biographer has said: "It began with a balance, but whether the emphasis would shift to *princeps* or senate only time could show." A no less grave defect was the lack of any law of succession, mainly due to the anomalous position of Augustus himself. Having received his office from the senate, the latter could name his successor or end the office entirely as merely a temporary one. If a legal succession had existed, the grave troubles of 69 after the death of Nero, and those 123 years later at the death of Commodus, when the empire was sold at auction to the highest bidder by the pretorian guard at Rome—the most dramatic and disgraceful event in all history—would have been impossible. That Augustus, however, regarded his office as hereditary is certain, for throughout his long reign he had, in the absence of sons, regarded certain of his household in turn as his heirs; first his sister's son Marcellus, the darling of the populace, whose death at nineteen in 23 B.C. was immortalized by Vergil (*Aeneid*, VI, 861–87) in what have been called "the finest lines ever inspired by untimely death"; then his grandsons Lucius and Caius Caesar, whom he loved, but who died in A.D. 2 and 4 respectively; and lastly his stepson Tiberius by Livia's former husband, the conqueror of Noricum, whom he hated.

Nothing was more characteristic of the real nature of Augustus than his spiritual interests, especially in art and letters. His patronage has given the name "Augustan Age" to subsequent epochs when classicalism has flourished. He followed Caesar's plan of restoring or erecting great public buildings—temples, theaters, porticoes, baths, arches and his own mausoleum—mostly on Greek or Oriental models which he had seen on his travels. In his "Memoirs" he says he "found Rome a city of brick and left it one of marble." But he is more to be remembered for his encouragement of literature. On his age three great poets have shed unfading glory, Vergil, Hor-

ace and Ovid, whose elegant grace and polish made them true offspring of his peaceful reign. Political peace, appreciative patronage, leisure and a cultivated audience as well as inspiration from the older Greek past had all conspired to create a "Golden Age" of letters. Rome's most popular historian, Livy, also graced that court and his "History of Rome," the flower of Latin prose, its style and diction faultless, though it, like the works of the poets of the age, lacked originality so characteristic of Greek letters, has been called "the funeral oration" over the grave of the Republic, for he idealized Rome's past and found consolation for the present in the old Roman ideals. Similarly, Vergil, who had lived through nearly forty years of political disorder only to pass his last years under the Roman peace of Augustus, embellished in incomparable verse the great Roman tradition of Aeneas and the Trojans settling Italy and their descendants founding Rome, and also expressed the ideals of her future. For he gradually became imbued with the splendor of Rome's mission to rule, as we see in the beautiful line from Anchises' prophecy to Aeneas (*Aeneid,* VI, 852):

Tú regeré imperió populós, Románe, meménto.

In his poem is embedded an epitome of all Roman culture, even as that of the later Middle Ages is found in the Divine Comedy of Dante, who regarded him as his master and model. Augustus' own *Res gestae,* the summary of his stewardship, promulgated at his death by Tiberius and inscribed on plates of bronze set up before his mausoleum and copied elsewhere, may still be read in the two imperial languages, Latin and Greek, on the walls of the ruined temple of *Rome and Augustus* in far-off Ankara (Ancyra) in Asia Minor—now the capital of the Turkish Republic. These "memoirs" give us a picture of Augustus the statesman, while his proclamations and sayings give us a picture of Augustus the man. They furnish us the outline around which the whole story of his policy and reign can be written.

In old age Augustus, ever frail and now worn out with his attempt of nearly a half century to found a stable government, and cast down by public worries—conspiracies against his life and especially Varus' defeat in Germany, and by domestic griefs—the deaths of many relatives and the erring career of his only daughter, Julia, a "princess" in licentiousness—resolved to take a holiday by accompanying Tiberius part way on his journey to Illyricum, sailing along the Tyrrhenian coast to Capri and going inland as far as Beneventum. On returning through Campania he fell ill at Nola, where he had been born nearly seventy-seven years before. Suetonius tells us that in his hour of death, after Tiberius had been recalled and Livia and friends had reached his bedside from Rome, he called for a mirror and, after having his hair combed and his shrunken cheeks adjusted, asked "whether he seemed to have played the farce of life well,"[1] adding two lines from a Greek play:

If all be right, with joy your voices raise
In loud applause to the actor's praise—

words which symbolized his character and policy. Then, left alone with Livia, he admonished her "to live mindful of our union" and expired on August 29, A.D. 14, on the anniversary of his first consulship in 43 B.C., the first great Roman to die peacefully in his bed since Lucullus, the conqueror of Mithradates, seventy years before. Then over his body brought to Rome Tiberius and his son Drusus delivered addresses, and it was burned in the *Campus Martius,* when an imprisoned eagle was released and flew into the sky, a symbol that Augustus was now with the gods, and Livia laid his ashes in his tomb.

[1] *Ecquid videretur mimum vitae commode transegisse,* Suetonius, "Augustus," 99.

We, like his deathbed friends, must say he had well played "the farce of life," for it is hard to find in history a career longer or more full of trouble than his, begun fifty-eight years before when, a youth of eighteen, he had come to Rome to plunge into the turmoil caused by his uncle's murder, and now peacefully ended in the midst of the *Pax romana*. For over forty years, the longest reign in Roman history, he, to quote Professor Pelham, "had successfully played the difficult part of ruling without appearing to rule, of being at once the autocratic master of the civilized world and the first citizen of a free commonwealth. He had instituted a new world epoch and determined the course of empire for centuries; he had gained the affections of provincials and Italians, had pleased the commons and conciliated the nobles."

His work will always be differently judged as well as his character. Tacitus (*Annales*, I, 8–10) says that both friendly and hostile opinions were expressed at his death, just as the assassination of Julius Caesar fifty-eight years before "was regarded by some as a deed of unexampled atrocity, by others as an achievement of superlative glory." But all recent writers on his life from Dumeril and Gardthausen in the late nineties of the last century to Dessau and Holmes in the twenties of this—and some four new biographies appeared only last year—agree that his glory is that he founded a new state out of the fragments of the old, that which Caesar failed to do, a timely régime which kept Rome from centrifugal destruction and gave her time to work out her mission; and, above all, that he instituted the longest peace in history. None need, therefore, any longer follow the judgment of Voltaire that he was merely the destroyer of the Republic and of political liberty in the ancient world.

Our estimates must vary according as we consider the dubious means by which he obtained power, or the legal use of that power when won. It is only since Mommsen and his collaborators collected the inscriptional evidence and reduced Roman constitutional law to a science that we can discard much of the gossip of Suetonius and even of Tacitus, alone available to Merivale and his contemporaries, and so reach a reasonable verdict, by contrasting the ruthless cruelty of the triumvir with the mild rule of the emperor. He had begun his public life with one purpose—to avenge his uncle's death, and in exacting that revenge had been guilty of cruelty and readiness to sacrifice friend or foe alike. The proscriptions of 43 B.C. are among the worst crimes of history, and his failure to save his friend Cicero the worst blot on his name. And here Augustus must shoulder a part of the blame, and entire responsibility for the destruction of Perusia. In palliation, if there be room for a gentler judgment, we may urge his youth and the long duel with rivals and allies who were older, without pity and intriguing to destroy him. In the course of that struggle he came to see that his great goal was not revenge, but mastery of the Roman state. To attain this he used every art, but when the struggle was over his real nature came forth, for he devoted the blameless remainder of his life to the reconstruction of the state and the happiness of his people. Then intrigue, deceit and cruelty were laid aside, and he became the true statesman, willing to rule only with justice and legally with the senate. It is from that period that the benevolent and placid features of his great portrait-statue from Prima Porta look down upon us. And it is for this that his name will always be found among the great ones of history—the unique *Imperator Caesar Augustus*.

SCIENCE AND SOCIETY

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THE title of this address is comprehensive enough to cover the whole gamut of human experience since that day in the distant past when the first primitive man stood upright and realized that he was different from other animals. The word "science," in its broadest sense, might be taken to include all knowledge, while "society" is certainly descriptive of the long succession of communities that have come into existence since the dawn of time.

Since I do not wish to range so far afield, and cannot aspire to the historical erudition that has made such a task possible for Professor Arnold Toynbee, I shall begin by specifically defining the scope of this analysis. By the term "science," I mean only those new discoveries from experiment and observation that have steadily enlarged man's accurate knowledge of himself and his environment, excluding for the time being writings that are purely intuitive or depend solely upon the imagination of the author. As to "society," I shall use that term to include the communities of western Europe and North America—the area of what has been called "western civilization"—and to exclude all others. This use of the word does not imply any superiority inherent in the members of western society; it simply emphasizes the fact that the other societies at present existing in the world have developed along rather different lines, and that mankind cannot be treated as a single unit for the purpose of this analysis. Finally, as to period, I wish to confine my remarks to the four centuries between 1475 and 1875, with some brief discussion of the subsequent years by way of epilogue.

Defined in this fashion, the problem is still a large one, but it has a definite significance. During this period, western civilization was revolutionized. At the beginning, we find the crystalline organization of medieval society, compact and conservative: at the end, the world had been knit together by developments in transportation and industry, while society showed signs of flying apart and was far from conservative. To what extent was this change due to the impact of science?

THE PARADOX

Any survey of the answers that have been offered to this question, and they are legion, reveals a distinct cleavage of opinion. The apologists of science are filled with such joy that their words are a continual paean of praise: science has made all things new. Science has created a better world than any that existed before: mankind should "rejoice and be glad therein." But the critics are equally vehement. They suggest that the progress of scientific discovery, and its implementation by enterprising business men, has destroyed the old social values and disorganized society. They look not to the psalms for their slogan but to "Pilgrim's Progress" and, with one of the most sensitive among men, cry aloud, "What shall I do to be saved?"

Such a confusion of witness cannot lightly be dismissed. No honest man can seriously suggest that the controversy is simply a battle between truth and falsehood, unless he is convinced by some inner light (which science cannot record) that his own interpretation is the true one, and that all those who disagree with him are numbered among the Sons

of Belial. For most of us, there is something to be said on both sides of the argument. Defenders of scientific discovery can point to the tangible results that science has produced, but how will they answer a man like Lord Stamp (whose mind is certainly as brilliant as that of the scientists he reproaches) when he pleads for a moratorium on inventions?

We are confronted by a paradox at the outset of our inquiry, and can only proceed if we recognize that the defenders and the critics of science are both accurate, in the light of their basic assumptions. But we must go further than that. It is apparent that the impact of science on western society, during the period under review, has not been a simple one. Omelettes are not made without breaking eggs, and it may clarify our thinking if we separate the constructive effects of science from those that have been purely destructive.

The Constructive Impact of Science

In a congregation of scientists and scholars, there is no need for me to describe in detail the magnificent achievements of scientific discovery. The steady growth of human knowledge has made it possible for scientists and technicians to work miracles with the natural resources that surround us, revolutionizing the material fabric of society by their activities. A few summaries must suffice to indicate the full impact of science in this respect.

If we take the broad group of the physical sciences, which include engineering as their handmaiden, we are amazed at the results that have been achieved. In regard to industrial production, men have harnessed the powers of nature to the wheels of complicated and precise machines in such a way that the burden of human labor has been greatly reduced. Men can produce the commodities that they have always used with a fractional part of the effort that was required two hundred years ago, and can also produce a galaxy of new articles that contribute to the comfort of life. Allied with these developments in the industrial field are the equally significant strides that have been made in transportation and communication. As many a political orator pointed out during those halcyon days of the nineteenth century, when men believed fervently in free trade, each of us is apt to find on his dinner table products that have been brought, cheaply and expeditiously, from every corner of the earth. We can travel with such comfort and celerity that it is easier to get from Montreal to Melbourne to-day than it was for Charlemagne to go from Paris to Rome, while the invention of the radio and telephone enables us to exchange views with every part of the world without leaving the comfortable armchair in which we sit. The magic carpet that appears so often in the stories of the Arabian Nights was less marvelous than some of the gifts that science has offered to every man—and, even in the fantasy of those stories, there were but few individuals who owned magic carpets or had the power to command jhinns!

When we turn to the medical and biological sciences, the same tale of successive miracles must be told. The average life of men and women has been steadily increased, as a result of diminished infantile mortality, better sanitation and the steady progress of medicine and surgery. The span of man's years during the middle ages had fallen far below the "three score years and ten" that were deemed reasonable during the epoch of the Cyriac civilization, but the progress of science has more than recovered the lost ground. Moreover, although I speak subject to the correction of the neurologists and psychiatrists who sometimes cast doubt on the assertion, the average man and woman to-day enjoys

continuously better health as well as longer life.

Turning to still another group of sciences, the one that includes geology, agriculture and chemistry, we are con-confronted with a record of steady increase in the number and variety of the products that are made available to us on the market. Agriculture has enlarged the selection of foods that we can eat, while chemistry has made it possible to preserve those foods so that they will be available at all seasons. Agriculture and geology have revealed new raw materials for industry: chemistry has transformed them into a thousand articles that minister to human comfort and enjoyment. Queen Elizabeth was delighted to accept, as a unique luxury, the first pair of silk stockings, but those stockings would now be regarded as uncomfortable atrocities by the girl who can purchase for a few cents an infinitely more attractive pair made of nylon or celanese.

I shall not prolong the catalogue, since it is familiar to you from the enthusiasm of many panegyrics. Modern industry and big business, in order to evade the issue raised by the critics of scientific progress, have used all the resources that they command to advertise the fact that the material comforts now available to the average man are greater than those that could be obtained by Charlemagne or William of Normandy in the days of their greatest power. There is no need to prove the existence of something that is apparent to every observer who is familiar with the history of the recent centuries.

The Destructive Form of Science

But what about the other side of the picture? What arguments can the critics find that will have weight enough to influence our judgment when there is so great an accumulation of material evidence to attest the benefits of science?

It has been well said that "man shall not live by bread alone." Society is not a number of individuals, each leading a separate existence, nor is it a mob drawn together by the excitement of the moment and composed of people who have nothing in common except their reaction to that excitement. Society is an organism which we can envisage as endowed with a kind of independent life that enables it to continue in existence despite the procession of births and deaths that determines the lives of the men and women who compose it.

I do not want to push this vitalistic concept too far, and am using it rather for illustration than for argument. The significant fact, which must be emphasized, is that men cannot live together in a society unless there is a dominant philosophy or ethos that they share in common. The ideals towards which society is directing its efforts, and the standards by which the conduct of its members will be judged, must be comprehended (however dimly) by each member of the group. When that common philosophy is lost or there is dispute as to the aims of the community the society comes to an end.

This fact is significant. A criminal gang, such as that ruled by Al Capone in Chicago a few years ago, may constitute a society. As long as its aims and standards of conduct were recognized by all its members, it was able to withstand the pressure of governmental action and public opinion, but it collapsed rapidly when these conditions no longer existed. The story of the Roman Republic could be told in the same terms, as could that of any of the great civilizations known to history, since common ideals and a recognized standard of conduct are the binding forces that unite men into a single society much more effectively than that economic interdependence which has been discussed *ad nauseam* during the last hundred years.

Scientific discovery, *per se,* does not

have any direct effect upon the ethos of society, since science is concerned solely with facts and methods rather than with the ethical implications of those facts. But we must remember that the average man is neither a scientist nor a philosopher. His concept of the aims and moral standards of the society in which he lives are apt to be the result of vague traditions and dogmatic inculcation, rather than of any clear thinking on his own part, and this concept may be seriously damaged by the discoveries of science.

Here we are dealing with something much less tangible than the physical impact of scientific knowledge upon those material resources of the world that constitute the environment of society. We are concerned with a climate of opinion, in which the social consciousness of scientific progress is in conflict with the old ideals and traditions, and it is important to realize that the true impact of science is not in this respect to be measured by accurate knowledge of the results of laboratory experiments but by the general public's concept of the nature of the discoveries. The average man listens to gossip and reads the newspaper: he does not study scientific journals. His concept of scientific discoveries would often horrify the trained scientist, since the average man seldom troubles to remember all the limiting conditions within which a particular statement holds true. The discovery of U–235 is not to him the partial verification of an interesting hypothesis: it is the creation of a new fuel that will drive the *Queen Mary* several times around the world if a couple of pounds of it is placed in a tub of water. Yet, inaccurate and dangerous as they may seem to us, we must concern ourselves with these popular concepts of scientific progress if we wish to understand that destructive impact of science on society which has aroused so many critics during recent years.

Man's Changing Concept of Himself

Even though we may not share the sentimental enthusiasm of Cobbett or Hilaire Belloc for the society that existed in the middle ages, we realize that medieval social philosophy was utterly different from anything that has followed it. Man was at the center of the universe. God had brought him into existence as the crowning act of all creation, on a world that had been made specially for his benefit. The sun was created to light him by day, and the moon and stars performed the same office by night, as all the heavenly bodies rolled steadily around the earth in their appointed spheres. Moreover, the Son of God had come down to earth and offered himself in a unique and awful sacrifice, in order to redeem man from his sins and offer him the hope of eternal blessedness.

And what of man, what was his duty in this vast creation? The question could be answered in one phrase: "To love righteousness and do justice." Under the guidance of the church, man was required to live this life so that he might qualify for salvation in the next, and that injunction was two-fold. Although the first commandment ordained that he should love God and worship Him, the injunction that man should love his neighbor as himself was just as specific. Even though the actual situation may have fallen far short of the ideal, the whole structure of feudalism (and of the early guilds in towns that broke away from feudal control) emphasized the fact that each man was his brother's keeper. Society was an organism, a poor reflection on this earth of the perfect celestial society above, and each individual had his appointed place. His rights and his responsibilities were both clearly defined, and the standards of justice were quick to condemn any evasion of responsibility. Just prices and just profits, the duty of a master to his servant, and all

the injunctions of Thomas Aquinas, must be set against the writings of Adam Smith if we would truly appreciate the extent of the contrast between medieval society and our own.

This contrast is, I think, due more to scientific discovery than to industrial and commercial developments (since the latter are not incompatible with a medieval philosophy), and there have been three great stages in the process of evolution. In each case, the change in the ethos of western society occurred slowly, as the realization of scientific discovery seeped into social consciousness and became, almost unconsciously, a factor influencing the prevailing climate of opinion.

The first impact came with the Copernican revolution in the field of astronomy, which can conveniently be dated by the publication of "De Revolutionibus Orbium Celestium" in 1543. Scientifically, it might be suggested that it made little difference to human happiness whether the sun moved around the earth or the earth around the sun, yet the tortured story of Giordano Bruno's vacillation during his trial shows the extent of that contrast in terms of contemporary philosophy. Copernicus and Galileo shattered the medieval cosmogony. The earth was no longer the center of the universe: it was a blob of mud whirling around a flaming orb and, throughout the infinity of space, the stars were other suns that might well be surrounded by other planets. There might be hundreds of other worlds, each peopled by men, so that God must have repeated the act of creation many times, and the Son of Man offered himself anew for the redemption of each planet. The idea was unthinkable, yet could not be dismissed. Medieval society had rested so firmly on its belief that this earth was the center of the universe, and humankind the chosen people of God, that the new science was devastating in its effect. During the agonies of the Reformation serious men attempted to reshape both religion and philosophy, while others sought relief in the agnosticism of the new learning, but neither were able to pour the new wine into the old bottles and preserve the vintage.

The discoveries of Newton, and the birth of modern physics, struck another blow at the old philosophy by entirely removing God from the universe. It was not the angels who guided the planets, but the force of gravity. The universe was not a miracle that operated only because of the watchfulness and loving care exercised by God the Father: it was a machine that responded to the laws of physics.

Nothing would have saddened Isaac Newton more than this bald statement which, as a godly man, he would have denied with all the force that he could command. But the average man of the seventeenth century did not read the "Principia" any more than his descendants study the scientific publications of Einstein. The mechanistic philosophy (which underlay the emasculated deism of a Chesterfield) was the result of the impact of Newtonian physics on the prevailing social consciousness, and the older conception of a divine order of society vanished. Even the serious religious leaders made no effort to restate social philosophy in its broadest sense, but attempted rather to emphasize the doctrine of redemption and the loving-kindness of God toward the prodigal that ultimately returned. It is hard to find anything brave or constructive in the activities of Isaac Watts during the years when he lived in sylvan luxury at Abney Park!

Both of these blows had been purely destructive: they shattered the fabric of the old society without offering any new philosophy of constructive purpose to replace the warmth of the imagery that they destroyed. But biology came to the rescue during the nineteenth century.

Darwin's "Origin of Species" appeared to offer final proof of the theories that Lamarck and others had formulated a generation before, and the gospel of evolution became a significant part of the climate of opinion.

I say "gospel," because the idea that gripped the public mind was vague and evangelistic. It possessed none of the scientific caution and precise formulation for which Darwin himself was famous. The doctrine of the survival of the fittest created in the public mind the certainty that anarchy was safe and desirable. The struggle of tooth and claw was considered to be as appropriate in the field of industry, as it was assumed to have been in regard to the natural selection of living species in a jungle existence. The greater the struggle, the more certain it was that only the fittest would survive. Failure served to demonstrate the unfitness of the individual in question, and anybody who should be so antisocial as to offer charitable aid to his weaker brethren was only retarding the inevitable progress of western society.

Once again, it must be remembered that the realities of daily life did not—fortunately for many of us—carry out the full rigors of the contemporary philosophy. Men are creatures of emotion and habit. They did not adopt in all their relations the ruthlessness of nineteenth-century philosophy any more than their ancestors had created in perfection on this earth the ideal society described by the Canonists. But our grandfathers did believe in the gospel of progress with all the fervor that was in them. The mere fact of success demonstrated the fitness to succeed, and since success made more noise than failure, it was obvious that society was moving steadily forward.

The Nature of the Social Sciences

The social sciences have not, as yet, been mentioned in this account of the impact of scientific discoveries upon the ethos of western society. The omission is deliberate. Despite the excellent work of the Encyclopaedists in France and the multitude of pamphlets on economics and politics which appeared in other countries, the prevailing climate of opinion was scarcely influenced by social and economic considerations until the beginning of the nineteenth century. The social sciences were born at a moment when the impact of natural science had already sorely damaged the ethos of western society; at a moment when mankind was vigorously entering upon a competitive struggle for the accumulation of natural wealth.

Within a single generation, however, the social sciences were characterized by an internal controversy that is peculiarly their own and has been used by critics to taunt their disciples ever since. Adam Smith, who was a moral philosopher rather than a specialized economist, had outlined, in "The Wealth of Nations," an optimistic philosophy of individualism and progress that might fittingly be regarded as the hypothesis that foreshadowed Darwin's work in the biological field. But Sismondi, who looked at war-torn Europe after Waterloo, found conditions very different from those that Smith had observed in eighteenth-century England, and challenged the whole gospel of laissez-faire.

This internal controversy, which still persists, arises out of the subject-matter with which the social sciences deal. They are concerned with human beings, with individuals of different training and wide varieties of emotional response. Conscious experimentation is not open to the social scientist who wishes to test his hypotheses, and since macroscopic observation is not always easy (because the social scientist does not live any longer than the men who he is studying, nor is he endowed with any greater powers of observation) he sometimes develops a

tendency to introspection. By analyzing his own response to a given stimulus he tries to judge how other men would respond.

Such an attitude is far from scientific, and critics who like to generalize have suggested that there are no such things as social *sciences*. They have condemned the whole business out of hand, and insisted that there can be no science without experiment. Nothing could be further from the truth. The paleontologist, without the aid of experiments, has made important contributions to the fund of human knowledge, and the meteorologist has solved many scientific problems, although he has no control over the phenomena he studies. Astronomy is among the oldest of the sciences, and seismology is to-day accorded scientific status, yet controlled experiment is impossible in both of these fields. The fundamental features of any science are useful hypothesis, accurate observation of data and utter devotion to truth, and I know of no reason that prevents the study of men and of society in scientific fashion.

The task that confronts the social scientist is not, however, an easy one. As we look backward at what has already been done, we realize that it is not the difficulty of observation that has limited the usefulness of the social sciences, but the pressure of custom and tradition. Since the political scientist has human prejudices, it is hard for him to forget his instinctive veneration of the British Crown (or the Constitution of the United States) when he sets out to study the efficiency of government. The problems with which the social scientist has to deal arise directly out of an environment that is so ingrained a part of his own habits of life that it is hard for him to get far enough away from it to formulate constructive hypotheses for study. Over and over again, we have seen that an individual from a totally different community will offer the best explanations of particular conditions in our own, and provide solutions that had not occurred to men already steeped in the traditional environment of the problem in question.

Social Science as Religion

As a result of these difficulties, the social sciences have developed along two divergent lines, and the exponents of the two methods of approach are getting further and further apart.

The first group of writings consists of a steadily growing pile of monographs that deal with specific problems, and it must at once be admitted that many of these are of first-class quality. As examples, one might cite the work that has been done in the field of industrial organization, the financial studies of borrowing corporations that are daily undertaken by the research staffs of our larger banks, and (on a wider canvas) the studies of population and national income that have appeared during the past five years. Even the best of these studies have had little or no effect on the ethos of western society, since they are concerned with narrow problems of method, or with aspects of economic activity which (despite their importance) directly affect the conscious lives of very few individuals, while the worst of them are scarcely useful for the specialist. As a matter of fact, some of the specialized studies in this latter group appear to have been undertaken, not because the investigation seemed of fundamental importance to the scientist but because there was a plenitude of data available, so that elaborate statistical techniques could be applied with little trouble. Indeed, there is reason to think that availability of data in handy form has done much to inspire hundreds of the monographs that now accumulate dust on our library shelves, and it would require more mental courage than I pos-

sess to suggest that society would be any better off if all of them were brought from their resting place and studied carefully by other social scientists. The man who complains that the reading public is not interested in his work should first ask himself whether he has, in fact, discovered anything that is of real concern to society.

The significance of this remark is apparent if we study the fate of the second group of writings in the broad field of social science—the writings that are frankly evangelical. Although Marx was an avid (and in some ways brilliant) student of history, his theory of the rise of the proletariat and his analysis of the causes of business crises do not arise directly out of his historical investigation. Yet it must be admitted that, for every man who to-day reads Marx in order to study his specific contributions to economics and history, there are thousands who believe fervently in his gospel of the proletarian revolution. Even if Marx was wrong, he was writing about a problem of deep significance to many men, and he was imbued with a serious realization of his mission. I know of few more interesting things in the history of economic thought than those passsages in the correspondence of Marx and Engels, written during the panic of 1847, when those two serious economists were learning to ride, and busily studying military strategy, in order that they might lead the masses when the final revolution occurred.

The case of Adolph Hitler is even more pronounced. You can read *"Mein Kampf"* from end to end without finding any evidence of economic, sociological or historical research, and nothing that we know about the author suggests that he is devoted to scientific habits of truth in reporting, and perseverance in investigation. The volume is frankly evangelistic. It attempts to show men the way to what Hitler regards as salvation, and, unfortunately, millions of its readers have become converted to the gospel.

This type of literature, much of which is now classed under the heading of social science, is not scientific at all. Karl Marx and Adolph Hitler, St. Simon and Robert Owen, all these are evangelists or philosophers (call them what you will) who are attempting to offer to society a new religion and a new ethos. They recognize that the march of scientific progress has destroyed the old philosophy, with its clear aims and fixed standards of judgment; they recognize, too, that the philosophy of laissez-faire and inevitable progress which dominated the nineteenth century is not rich enough to satisfy mankind or comprehensive enough to serve as the effective bond for western society. In place of the worship of God and the elevation of man, which inspired medieval society, they would place the revolution of the proletariat or the deification of the state.

The Present Problem

The evangelists of autarchy and communism are not alone in their realization that all is not well with the ethos of western society. Thoughtful men, in all countries, have grown less sure of the slogans that their fathers shouted so exultantly, and it has become amply apparent that mankind has not yet learned to use its new-found wealth with wisdom. The pains of the business depression that we suffered yesterday and the horrors of war that we endure to-day suggest that we have not yet created a perfect society.

But no thoughtful man will be inclined to accept, as a gospel of salvation, the Nazi version of a policy that Diocletian adopted as a last desperate resort in the hour when the Roman Empire was crumbling. Progress does not lie in the direction of a retreat that would compel us to abandon most of the things that mankind has striven through long centuries to attain, and we do not wish to

solve our problems by crystallizing society on a low level of material well-being. To-day we recognize more clearly than ever before that our ideals are more precious than our goods and, by the very recognition of that important fact, we perceive the dichotomy of our problem. Each aspect of it demands separate consideration.

In the first place, we must define clearly the philosophy of our society. What are the ideals that it cherishes? By what standards will it judge its members? This is not a scientific problem, and it is not capable of solution by scientific methods. It concerns economics no more than it concerns physics, since science merely shows what will happen if we do a certain thing and remains silent as to the wisdom of the act.

But this problem is of direct significance to every one of us as members of western society, since the life of our society depends upon the fact that we do share common ideals and that these ideals are strong enough to hold society together during both prosperity and adversity. Moreover, we must bring to our study of this problem (even though it be labeled religion or philosophy) the same love of truth and the same desire to investigate that characterize our work in the narrower scientific fields. All too often, we have seen the scientist become a man of prejudice as soon as he leaves the laboratory, so that his attitude before the ballot box shows none of the patience and judgment that appear in his professional writings.

It should also be emphasized that our decision on this problem of social philosophy must be as specific as the decision on any scientific question. All of us, in this hour of our nation's crisis, believe so fervently in the ideals of democracy and liberty that we are willing to sacrifice ourselves and all our goods for their defence. But have we clearly defined those ideals? What is our attitude toward the conflict between national sovereignty and an organized world? How do we define "the ideals of democracy" in regard to such things as freedom of trade, social insurance and migrations of people? How can we ensure the welfare of society and yet preserve the freedom of the individual? At the present moment there is no clear answer to these questions from western society as a whole, yet this broad problem of social philosophy must be solved before we can expect that the impact of science will become wholly beneficial. We must know what we want to do before we can expect our tools to be of use.

The second problem, which becomes more important as soon as the answer to the first has been clearly given, is that of adopting means to ends. Even though our social scientists have no responsibility, as scientists, for the socialization of ideals, it is reasonable to expect that they will show us how to attain those ideals once they have been clearly stated. A clear solution of the philosophical problem defined above will naturally point the way toward the formulation of more fruitful hypotheses in the field of economics and political science, so that we may expect an integration between the two divergent types of work that we have noticed in the broad field of the social sciences. Specialized monographs might be expected to deal with more fundamental problems while comprehensive studies would naturally be expected to be established more directly on the foundation revealed by specialized studies. Moreover, investigations of the kind that are contemplated here would naturally involve on the part of the social scientist considerable knowledge of the things that are being done in the fields of the physical and natural sciences. We need an integration not only between comprehensive writings and specialized monographs but a further integration that brings into focus the significant

results that have been attained by scientists working in other fields.

The adaptation of means to ends; the charting for society of a course that is most appropriate in the light of the existing fund of human knowledge, is the primary function of the social sciences. It will not be an easy task, but its importance should call forth the finest efforts of every individual. Moreover, the work that has been done during the past few years is sufficient to indicate that social science can offer splendid contributions. The analyses of national income and capital formation made by Dr. Kuznets, in the United States, and the comprehensive study of the financial system that is now being made by the National Bureau of Economic Research, provide just the kind of information that we shall need for the rehabilitation of society when this war is over. Even more important, these studies have developed a method appropriate to the macroscopic investigation of economic and social phenomena, and have shown the way in which further studies can be made that are of more direct significance to Canada and to the world.

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Looking backwards, therefore, it is apparent that the impact of science on society has not been wholly beneficial. The ethos of western society has not responded to the changes in its material environment, so that to-day we face a major crisis. Even though everyone of us confidently expects that the democratic powers will, in the long run, attain a military victory in the present struggle, that victory will not solve the problems that confront us. Western society is as much endangered by the slow process of crystallization as it is by military assault. But if we are willing to face the major problem of deciding upon our ideals, the forces that science has placed at our disposal are already sufficient to make the attainment of those ideals a practical possibility.

FLAGS AND BOUNDARY LINES

For an organization like the Rockefeller foundation which over many years has tried to carry on its work regardless of flags or boundary lines, these are unhappy days. To sit by and watch the disappearance or decadence or, worse, the perversion of institutions of learning which in earlier and better years we were privileged to assist is not an easy assignment. In the decade that followed the war these institutions gave high promise in public health, in medicine and in the natural and social sciences. The Institute of Hygiene at Warsaw, the Institute of Public Health at Prague, the Kaiser Wilhelm Gesellschaft in Berlin, the Institute of Psychiatry at Munich, the Institute of Inorganic Chemistry at Göttingen—these were a few of many organizations, in a world where thought was free, to which the foundation gave needed assistance.

Even more difficult is it to see the brilliant men with whose work we were associated—many of them on fellowships or with grants in aid from the foundation—now driven from the posts for which they were trained, debarred from their laboratories, some of them fugitives, some in concentration camps, many of them separated from their families or lost in foreign countries where they sought haven. To these scholars scattered in many lands, whose lives are now a sacrificial testimony to the principle of intellectual freedom, we in this protected hemisphere pay tribute of admiration and homage.

The development of the war has had the further effect of driving back several of the foundation's outposts established in connection with its own operating program around the world. Our Paris office has been closed and the Shanghai office transferred to Manila. A temporary office has been opened in Lisbon. Our personnel has had to be recalled from Egypt, where work was being carried on in malaria and schistosomiasis; from Turkey, where we were engaged in sanitary engineering; from Rumania, where scarlet fever studies were being conducted; and from Hungary, which was a station for influenza research. However, foundation personnel is still operating on the Burma Road, in India, in South China, in the Belgian Congo, in Uganda (Central Africa), in Spain and Portugal and of course in Latin America.—*The Rockefeller Foundation Report for 1940.*

THE HAPPY ACCIDENT

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PROBABLY the most fascinating of all natural phenomena is that of creation—from the unknowable genesis of this terrestrial sphere itself clear on down to the emergence of some pat idea for a new tenpenny toy. What mysterious and diverse ganglia must fall magnetically into alignment, what vague and explorative star-groping must precede the sudden and spontaneous episode of the birth of an idea, like a rain-drop globulating in a fog under the benign influence of some vagrant channel of chilled air?

In a letter to Dr. Caspar Wistar in 1807, Thomas Jefferson refers to "the slow hand of accident" transferring mysteries to the table of sober fact, as though a majority of the advances in science made up to that time had come by some such vicarious route. Probably the prevailing conception of scientific discovery is most popularly exemplified by Charles Goodyear's "accidental" discovery of the vulcanization of rubber. Every one knows and can visualize the picture of Goodyear puttering around in his humble kitchen with his fuming mixtures and clumsily upsetting his pan of india rubber and sulfur; the ensuing sputtering on the hot lid of the stove, and, lo, the great scientific discovery!

It is common to human nature to embrace such a happy accident. Who would not desire also to stumble upon some such chance fame and fortune? The drama appeals to every basic mentality. It is ever the short cut, the easy way, the avoidance of good hard honest sustained labor that is always so enthusiastically welcomed by the mass mind.

The radio, popular literature, the loose parley of the streets, all exalt such moments in the course of human progress as Goodyear's "lucky" and chance discovery. Not so prevalent, however, is the emphasis on all the substantial progress, all the hours of dull, minute and precise scientific prying that eventually crystallized in that sparkling moment of the spilled mixture. These are overlooked and disregarded as inconsequential, having no bearing upon the ultimate result. Yet the simple facts are that for ten long years prior to his moment of success, Goodyear had almost ceaselessly attempted to find a method by which rubber could be made to withstand the extremes of heat and cold. In 1837, two years before his happy accident, he had worked with a man who had made some experiments with rubber mixed with sulphur, and he had bought the right to use this unperfected process. The lucky accident could neither have happened to, nor the significance of it been appreciated by, any one without the prepared mind which Goodyear already had. Once again, as Pasteur had suggested, luck favored the man who was best prepared to make use of it.

It is not the lay mind alone, however, that is inclined to overemphasize the apparently easy or soft part of the scientific procedure to the disparagement of the long preparatory road that must be laid up to the mountain top before the scene can be unfolded. Direct criticism has come in recent years from higher circles of thought. Charges are levelled at science, citing its "pebble-picking" and its inability to digest satisfactorily the data already assembled. We have been told that there is a revulsion against science for these and other sufficiently

obvious reasons. This revulsion of course is not a new or isolated phenomenon. Partially it derives no doubt from the perversion of scientific progress in the utility of warfare; again, from the apparent slowness of science's advance in certain of the deepest human needs.

It has been implied that if more effort were made toward the extraction of general principles out of already known facts, perhaps for a time at the expense of the labor incident to collecting new facts, progress would be expedited and the factual material already on hand made more useful to society. To this proposal to put more emphasis on intellectual activity than is being done, and less upon the tools, one may agree in theory, in so far as it proves practical. However, the reaction of those who are impatient of recorded progress only too often expresses itself simply in the form of such proposals to modify or ignore the prevailing methods. That it is not feasible to suppose that the course of science can be charted on a schedule like a train, wilfully and intentionally, is clearly indicated by the observable data of its history.

But first, before science as such can be properly attacked, it must be defined; its boundaries and outlines must be made familiar. Sarton said that "Science is nothing but the human mirror of nature." That is a very satisfactory beginning, but it should be added that science, in dealing with the phenomena of nature, is characterized especially by its attention to their interrelationships.

That I am pessimistic about the outcome of attempts to expedite the progress of science or of the general applicability of its discoveries, by tampering with the method, will appear at once from my definition, for I propose to define the scientific method simply as that method which, as a result of centuries of experience, has been found to give the best results in the search for truth in the field of the unknown. The method consists of a mixture of intellectual activity and technique or tools. The proportions vary within wide limits, but the method is incomplete without either of its ingredients.

Many volumes have been written on the philosophical and metaphysical implications of science. Since I am taking a rather pragmatic view of science and of its place in human affairs, we may omit most of the philosophical background. We must, however, I believe, say that there is no such thing as absolute knowledge or absolute certainty, and that the quest for ultimate causes is not our concern. Science operates within a framework which for practical purposes is tacitly assumed to be fixed. We have recently had, thanks to Mr. Einstein, an illustration of what happens when the framework itself is shaken or destroyed. We have seen that science itself does not collapse. It merely becomes necessary to rebuild within the new framework.

Systematic scientific knowledge is founded upon certain theories, postulates or concepts which by almost universal consent are regarded as true, even though they are incapable of direct proof, as long as they serve to support the vast structure which is built upon them. For example, there is the theory of evolution; also the belief that there is such a thing as reality in the material sense, and the doctrine of cause and effect. Science does not depend upon these specific beliefs or postulates, but it should be clear that science rests upon these and other postulates so long as they prove useful in arranging our knowledge—and no longer. The overturning of any of these postulates would mean a rearrangement of knowledge but not a destruction of science—since by definition "science is nothing but the human mirror of nature."

It thus becomes clear that science deals

not with facts, in the absolute sense of the word, but with the most probable explanations of observable phenomena. While it is a common practice to speak of scientific facts, it should be understood that a statement of so-called fact represents the truth only if a whole series of fundamental postulates are true. Recognition of the most probable as the ultimate attainable by science and the scientific method has led to the wide use of statistical methods, and the treatment of data from the standpoint of the theory of probability.

How, then, does the scientific method actually work; what are the procedures followed by a scientist in his daily life? From an analysis of the actual practice of the profession of a scientist perhaps we may come nearer to an understanding of the methods he uses.

First of all, let it be understood and accepted that the pursuit of scientific work, as with all creative endeavor, is first and foremost an art. There is an art of observation, an art of experimentation and an art of applying the intellectual process to the material with which the scientist works. There is something of a paradox in the statement that the scientist must be an artist, but nevertheless this is true; and to recognize this is of extreme importance. As Fagin said, "The true artist is the perpetual explorer. He cannot invent the substance of his work, but he can discover it in the life of nature and his fellowmen." So also with the scientist.

The pursuit of truth is highly individualistic, for in addition to each scientist, each field of work and each particular problem has its own individuality. All kinds of men with all kinds of equipment from the standpoint of intellect, knowledge and technique are engaged in scientific pursuits.

Sir Francis Bacon, who lived from 1561 to 1626, is generally credited with having given the first impulse to the creation of the scientific discipline as we know it to-day. The method which he formulated was to consist first in the collection of facts into a sort of natural history, and second in the drawing of conclusions from these facts by the logical process of induction, or reasoning from the particular to the general. He appears to have believed that the collection of all the necessary facts would occupy only a relatively short time, and that once in possession of the full supply of facts, mankind could work out all of its problems by reasoning alone.

Although it has been amply demonstrated that science has *not* progressed in the manner laid down by him, and although it is almost universally agreed by scientists that the Baconian method, taken by itself, is unworkable, there are still proposals, particularly in the newer fields of knowledge, to return to his method. Bacon omitted three of the most important features of science as we know it—the working hypothesis, experiment and deduction, or reasoning from the general to the particular.

To-day the scientific method which the scientist, adequately trained, equipped intellectually and technically, proceeds to apply, over-simplified, consists of the formulation of a working hypothesis, the planning and carrying out of observations, and/or experiments to test his hypothesis; revision of the working hypothesis as many times as may be necessary, and the formulation of a conclusion, which may or may not confirm the original hypothesis. From the conclusion, which, in the theory of logic, is arrived at by induction, other conclusions may be arrived at by the process of deduction. Thus when Einstein, on the basis of certain facts or theories, formulated a conclusion in the form of the theory of relativity, he predicted that rays of light passing from the stars near the sun must deviate from a straight path, if the theory were to hold true as a

generalization. The verification of such predictions is an important part of the scientific method.

Even from this over-simplification it is obvious that the scientific method is far from simple. It requires powers of reasoning as well as of observation and/or experiment; and it requires not only that these powers work together toward a common end, which is the search for the truth, but also that they do so without interfering with each other.

In actual practice the difficulties are even greater. We start with the formulation of a working hypothesis or a preconceived idea. Random collection of facts without a working hypothesis hardly deserves to be called science. The working hypothesis is supposedly formulated on the basis of all the facts known to the observer. The scientist now attempts to predict what will happen under a new set of conditions. Often he is content to say that one of a number of things will happen, and to leave the answer entirely to nature. But rarely does he do an experiment just to see what will happen, without any preconceived ideas.

He does an experiment and repeats it enough to eliminate experimental error. His working hypothesis must now be accepted, rejected or modified; or if he has a number of alternatives the number is reduced, and new experiments are devised to enable him to arrive at the correct hypothesis. He then examines his data for other possible explanations of the phenomena observed, devises new experiments to avoid ambiguities and finally arrives at a conclusion.

Now this immediately affords us an opportunity of indicating the position in science of the process of reasoning as compared with observation and experiment. The experience of every scientist, good or bad, is that the preconceived idea or working hypothesis—without which there is no science, but only dabbling—is a most unreliable affair, and that there is no substitute for submitting the idea to the criterion of the scientific method *in toto*, which includes observation or experimentation for verification. The true scientist has learned from his own experience that it is never safe to take one single step forward into the abyss of the unknown by the intellectual processes alone.

Perhaps this might be answered by the observation that scientists are not sufficiently trained in the process of logic; but it is clear that this difficulty, which is common to all scientists, is not due to a defect in the process of reasoning. Just as a mathematical problem can be solved only on the basis of the variables that are stated, just so can a scientific problem be solved only if all the relevant facts are included in the statement of the problem which led to the formulation of the working hypothesis. And it is precisely in the inclusion of all relevant material that the difficulty lies, for as soon as unknown territory is entered no one can predict what will be relevant and what irrelevant. Here genius lies in the ability to foresee the relevant and to ignore the irrelevant. It is apparent, therefore, that the powers of reasoning, taken by themselves, are incapable of leading to anything more than working hypotheses, whenever the field of the unknown is entered, and that the only safe scientific attitude is one of doubt with reference to unverified working hypotheses.

This applies with particular force to phenomena in which the variables are numerous and uncontrollable. We have abundant illustration of the truth of this in our abrupt attempts to modify the economic and social situation of the present. A great many individuals, among them many competent and well-informed economists, are attempting to predict what will happen as the result of certain administrative procedures. Their theories and predictions are in

fact working hypotheses, and when the President puts their recommendations into effect he is simply carrying out the next step in the scientific method—that of verification or rejection.

Similarly, the scientist must at all times be ready to drop his working hypothesis or to modify it to fit his observations. A great difficulty arises here in the all too human tendency to attempt to make the facts fit the preconceived idea. This is one of the hardest obstacles to overcome in any scientific work. An unexpected result is obtained or a wholly new phenomenon observed. The first impulse with nearly all investigators is to discard the unexpected as being due to experimental error, and thereby to close the mind to it, even though it is well known that out of such unforeseen observations may come the most brilliant discoveries. The scientist must consciously and deliberately train himself not to disregard observations which do not fit in with his preconceived ideas. The combination of "chance and the prepared mind" is still the best combination known for real discovery.

Quite properly there is importance in rational analysis, which may mean mathematical or logical treatment of facts, in contrast with empiricism, or the mere recording of observed facts. While I would be the last to deny the value of mathematical or logical treatment of factual material, I share the belief with many others that the processes of conscious formal logic have in the past had too high a value put upon them as tools of discovery. This is precisely for the reason that induction and deduction, in the formal sense, are useful only in so far as they can be applied to relationships already known to exist; whereas the essence of science is the discovery of new and unpostulated relationships.

Rational analysis is first and foremost the method of establishing or rejecting suspected relationships and of bringing order into observed and related facts. Without such analysis science ceases to be science. Rational analysis is also often of great value in postulating, and even in predicting, the nature of the unknown. Thus, from the behavior of the remainder of the solar system the existence of another planet in the system was postulated before Neptune was discovered, and the search for this planet was given direction. Also, when Mendelejeff discovered the systematic relationships among the atomic weights of the elements and formulated the Periodic Law, he was able, in 1871, to assert the existence of three new elements, so far unknown to the chemist, and to assign them definite properties. His prophecy was completely vindicated within the next fifteen years by the discovery of gallium in 1871, scandium in 1879 and germanium in 1886. Also, in several instances he questioned the correctness of accepted atomic weights on the ground that they did not correspond with the Periodic Law, and his judgment was vindicated by subsequent investigation. Such predictions —and the list is long—were the result of rational analysis. But in no instance did the rational analysis constitute the actual discovery.

That actual discovery may come through rational analysis alone is, however, not impossible. But it occurs only if the data or factual material at hand include all the relevant variables, as the result of a happy accident. If the relevant material is all at hand as the result of foresight, then another mental process begins, which Claude Bernard describes as follows:

> Apropos of a given observation, no rules can be given for bringing to birth in the brain a correct and fertile idea that may be a sort of intuitive anticipation of successful research. The idea once set forth, we can only explain how to submit it to the definite precepts and precise rules of logic from which no experimenter may depart; but its appearance is wholly spontaneous, and its nature is wholly individual.

A particular feeling, a *quid proprium* constitutes the originality, the inventiveness or the genius of each man. A new idea appears as a new or unexpected relation which the mind perceives among things. All intellects doubtless resemble each other, and in all men similar ideas may arise in the presence of certain simple relations between things, which every one can grasp. But like the senses, intellects do not all have the same power or the same acuteness; and subtle and delicate relations exist which can be felt, grasped and unveiled only by minds more perceptive, better endowed or placed in intellectual surroundings which predispose them favorably.

I believe that Claude Bernard is correct in his statement that "no rules can be given for bringing to birth in the brain a correct and fertile idea." However, in the light of modern psychology we can perhaps arrive at a better understanding of how such ideas do get born. It is my belief that the perception of a new or unexpected relation occurs almost always first in the unconscious. The scientific worker supplies the material to the unconscious by his conscious mental activity, time elapses, something clicks, and out comes the idea, fully born. It is not by any means always correct, but it is always suggestive. To the degree that the unconscious produces such ideas, and that they are correct and far-reaching, is the owner of the unconscious fortunately endowed for a scientific career. The genius is the man whose unconscious is exceedingly productive of "correct and fertile" ideas, and whose conscious mind is prepared to receive and act upon this product. Needless to say, this ability can not be inculcated by any system of education or training; it can only be given the opportunity to develop in a propitious environment.

I use the term unconscious to distinguish mental processes of which we are not conscious from those of which we are, and am chiefly concerned with its intellectual rather than its emotional attributes. These functions of the unconscious were described fully by von Hartmann in his book, "The Philosophy of the Unconscious," first published in 1868. That this function of the unconscious appears to have been lost sight of at the present time may possibly be due to the much greater emphasis put in recent years upon the role of the unconscious in the emotional life.

Accidental discovery comes most often to the man who has given much conscious thought to the problem upon which he is engaged and who is in a position to grasp, through both conscious and unconscious mental processes, the significance of any accidental observations he may make. Thus accidental discovery is most apt to come to the scientist who makes the greatest use of his faculties, including those of rational analysis. It is, of course, also clear that accidental observations occur only when the scientist is actively at work.

Futhermore, it is equally clear that the unconscious, even though it has a peculiar faculty of perceiving hitherto unsuspected relationships, can also deal only with that material which has been put into it. The unconscious must therefore be fed not only with factual material but also with relationships carried as far as rational analysis can go. Consequently, other things being equal, the better supplied the unconscious is with factual material and with the products of rational thinking, the more likely it is to produce new relationships. Contrarily, the unconscious can produce nothing out of a vacuum, and great discoveries are very unlikely to come from minds of poorly informed individuals, with inferior intellectual capacities. The superior quality of the unconscious is thus due not to any mystical properties, but solely to its ability to deal with a larger number of simultaneous variables than can be dealt with by the conscious processes of logical and mathematical analysis.

The peculiar position of the unconscious can perhaps be illustrated best by

an example of the type of thing it does. Most scientists carry in their minds a vast body of apparently unrelated material. A scientist may be engaged simultaneously on several aspects of the same problem. He analyzes his material in terms of known relationships, and often makes conscious systematic attempts to discover new relationships. In addition to his attempts at rational systematic thought, which in any case is more theoretical than real, and in addition to his mathematical treatment of his data, his conscious mind is busily engaged during most of his waking hours with the details and the general significance of his problem. He may make a new and perhaps accidental observation, or he may read in the literature of observations made by others. A new train of thought is started, which goes on—half consciously and half unconsciously. Finally, and perhaps more often than not, when he is not consciously thinking of the subject at all, the observation, seen in its proper relationship, often uniting other previously apparently unrelated phenomena, comes into his conscious mind as a flash of inspiration. There follows then much work to test and verify the validity of this new relationship; but the discovery itself has already been made.

This is the ordinary process by which a scientist proceeds. Brilliant and far-reaching discoveries have been attributed largely to accident or to genius. Yet both genius and accident require a background of knowledge, of work with facts, observation or experiments, and of preparation of the mind.

The same process applies to all creative work. Sir Arthur Quiller-Couch, in speaking of the art of writing, declared: "Let me assure you that in writing solid daily practice is the prescription; these crests only rise on the back of constant labour. Only out of long preparation can come the truly triumphant flash."

Napoleon, whose career was filled with "luck," believed this was equally true in the field of the military. He said that battles were won by the sudden flashing of an idea through the brain of a commander at a certain critical instant. The capacity for generating this sudden spark was military genius. Napoleon consciously counted upon it, always believing that when the critical moment arrived the wild carnival of confusion of the battlefield would be illuminated for him by that burst of sudden flame. But if Napoleon's mind had not been stacked with military facts, statistics, logistics and the theories of the past, if he had been ignorant of all the prosaic business of his profession instead of attending to it more closely than any other commander, would those moments of supreme clearness have availed him, or would they have come to him at all? Clearly he was ceaselessly storing away in his subconscious mind the silage upon which he was to feed in the great moment.

How many apples had fallen upon the earth before the one that germinated the law of gravitation in the mind of Newton? How many men had seen a lantern swing before Galileo's brain was so stimulated to create his most epoch-making astronomical discovery?

Roentgen was dabbling with some evacuated tubes as scientific toys when some fluorescent material which happened to be in the neighborhood of his tube glowed. Unwittingly he had discovered the x-ray. Proof that electrons are of the nature of waves resulted from the accidental breaking of a container of liquid air in the laboratory of Davisson and Germer. Raman was studying the scattering of light from benzene, toluene, etc., when on the photographic plates which he used, he discovered wholly unexpected lines, which were the result of the breaking of quanta, the bundles of energy that make up light. Galvani came upon knowledge of the muscle nerves and their reactions to electricity

through the accidental touching by his wife with a metal scalpel a frog upon a machine for generating frictional electricity. The stethoscope evolved out of a French boy's recollection of tapping messages to playmates at the opposite end of felled logs.

One day in Paris in 1875 a young man in a laboratory cut his finger and applied some collodion to the wound. The pain in the finger kept the young man awake at night, and he lay pondering over a problem that was continually in his mind: namely, how to find a suitable means of combining guncotton and nitroglycerin. He hit upon the idea that this might possibly be done more successfully with nitrocellulose which was only slightly nitrated than with such a substance as the collodion which he had just used. He went down to his laboratory at four o'clock in the morning and when his assistant arrived he showed him the first specimen of blasting gelatin which he had produced in a flat glass vessel. It consisted of nitroglycerin with the addition of a small proportion of a solution of nitrocellulose in ether.

Now in the equation cut finger + collodion + X = blasting jelly, who but Alfred Nobel could have served for Mr. X? His entire life, and the lives of all his family, had been devoted to experiments in explosives. His father before him was an inventor who had served the Russian government in the work of developing submarine mines. A precocious and brilliant student, Nobel was a terrific and a tireless worker, with more than one hundred patents to his credit. From blasting jelly he went on to smokeless powder and other inventions. Could the cut finger and collodion have resulted similiary for any one else? Not likely.

In trying for a $10,000 prize offered for a synthetic substitute for ivory for billiard balls, John Wesley Hyatt treated cotton cellulose with nitric acid and thereby obtained a substance which he called celluloid. Before that, however, Hyatt, who was a printer, was interested in developing a printers' roller material, and had patented a device for sharpening knives. Later he developed the famous Hyatt roller bearing.

In 1890 Dr. Adolph Spitteler, of Hamburg, was trying to make a white blackboard for use in his classroom. Whimsically he mixed sour milk with formaldehyde. The result was a shiny, horn-like substance—casein.

Dr. Leo Baekeland, of Yonkers, N. Y., in 1908, was trying to create a fusible, soluble material to substitute for the expensive natural resins, when by putting his mixture under high heat and high pressure he obtained instead an insoluble and infusible material now known as Bakelite, the first synthetic resin, created out of carbolic acid and formaldehyde. Baekeland had some 400 patents to his credit. He had created Velox paper and was a professor of chemistry before he was 24 years of age. He worked specifically on his problem for four solid years before his "happy accident."

There were recorded cases of gastric fistula before that of Alexis St. Martin, the Canadian *voyageur* of Mackinac Island, but it remained for Dr. William Beaumont to recognize opportunity in this historic accident and so become the pioneer of knowledge of the gastric juice and the processes of digestion.

In virtually all these and many other similar accidental discoveries, the event was not so much the accident itself as the understanding and interpretation of it by the alert scientist present on the job.

In the field of science, stepping aside from genius in its highest form, we find that most capable investigators approach problems in the systematic manner called the "analytical method" of research. In essence the method consists in taking a phenomenon apart to see how it works

and then putting it together again. It is a very important method, and one that should not be decried, for most of the solid advances in knowledge come, directly or indirectly, from the application of this method—either before or after the birth of an original idea. Certainly no one could have been more systematic than Darwin, who spent a lifetime in collecting observations out of which the theory of evolution emerged.

However, the systematic method alone is not apt to yield brilliant results, for the reason that it is usually impossible to isolate any phenomenon and to study every one of its factors. The systematic method, however, does orient the scientist in his problem, provides him with facts which may be arranged in orderly fashion by conscious mental effort, and so supplies the material which can be made use of by the unconscious.

In so far as there is disagreement between scientists themselves as to the relative value of the components of the scientific method, I suspect that the quarrel is between two different temperaments. One suspects the other of wishing to avoid hard work by the methods of "armchair science," while the other's fear is that too high a value will be put upon hard work as an end in itself. In point of fact there is no substitute for either the intellectual processes or for the hard work that goes into the making of observations and into experimenting. The immediate result of new hypotheses created by intellectual activity is, as we have seen, always the necessity of more hard work. The difference between the two schools is therefore more theoretical than real.

I pass over the "pebble-picking," or blind accumulation of unrelated facts, for in the extreme form implied by these words this hardly deserves consideration, though in actual practice there is often difficulty in drawing the line between pebble-picking and the purposeful accumulation of needed data.

It is the goal of every science, and of every real scientist, to arrive at such generalizations as are suggested, and in a minor way they are constantly being derived from existing knowledge. But generalization is more difficult than the proposal to expedite it by concentration would imply. The process of generalization requires not only study of the facts at hand, but also a key. The key may come from new observations, or from a new method, and with the key at hand the task of generalization becomes easy. But more often the key to generalization, as in the case of the individual problem, comes from the unconscious mind, and the observation that known facts fit the new generalization better than any previous hypothesis, and that new facts can be predicted from it, provide the support for the generalization. Now the finding of such generalizations is even more a mark of genius than is the case in the individual problem, and the fact that the really great generalizers can almost be counted on the fingers, including Galileo, Newton, Darwin, Pasteur, Mendel, Faraday, Einstein, should be sufficient to indicate the extraordinary difficulty of the process. And in each case the new generalization has resulted in the necessity for more rather than for less actual labor.

Certainly a worker whose own intellectual processes have not led him above the routine collection of facts can not be made into a generalizer by insisting that he devote some time to thought. Except in so far as a better understanding as to how the scientific method actually works may lead to improvement in our educational processes, it seems to me that science can do no more than to continue to progress by the combination of intellectual processes and good hard work, which makes up the scientific method as we understand it at present.

It is typical always of the inert theorists to prefer the happy accident, as such,

and to be impatient of the long drudgery of preparation and production. To them, the long "spring training" of the baseball pitcher would seem simply a waste of time. The ace should spring full-blown from the brow of Zeus onto the hillock and there proceed to improvise his form and technique for mowing down the opposition. It might be a more enjoyable world, to be sure, if all this were possible and likely; but human experience demonstrates conclusively that it is not.

To the professional theorists the crystallization need not require the heat and the bubbling cauldron. Columbus should simply have sat on a rock and imagined the outlines of the New World. Why bother with a boat? By chance, perhaps, Luckhardt came upon the sleeping carnations from the greenhouse; but it was a long, arduous and always dangerous progress from that happy accident to the invaluable discovery of the utility of ethylene as an anesthesia.

Who can say that there would still be these moments of crystallization without the innumerable, infinitesimal and infinite pressures? There is no basis for suspecting it.

THE ANNUAL NUMBER OF ECLIPSES

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THE following discussion is a more complete explanation of the annual number of eclipses than is generally met with, although the treatment omits those factors whose bearing on the results can be considered negligible. For the purpose of an orderly explanation, many fundamental concepts are introduced first.

The maximum annual number of eclipses is 7, five solar and two lunar, or four solar and three lunar, and the minimum is 2, both of the sun. Solar eclipses occur only at new moon, when the moon's shadow falls on the earth's surface; lunar eclipses occur at full moon, when the moon crosses the earth's shadow in the course of its orbital motion.

The plane of the earth's orbit is known as the plane of the ecliptic. Since the moon's orbit is inclined to this plane at an angle of five degrees, eclipses can only occur when the full or new moon is at or near the nodes (the two points at which the moon's orbit crosses the plane of the ecliptic). However, the moon need not be situated exactly at the node to cause an eclipse. As is shown in Figs. 1 and 2, the maximum distance from the node, measured along the ecliptic, at which the earth's shadow (or the sun from the opposite node) can be, for an eclipse of the moon is the lunar eclipse limit. The greatest distance the sun can be from the node at time of new moon, and cause an eclipse of the sun is the solar eclipse limit.

There is a range in the eclipse limits since the radii of the orbits of the earth and moon vary with their respective

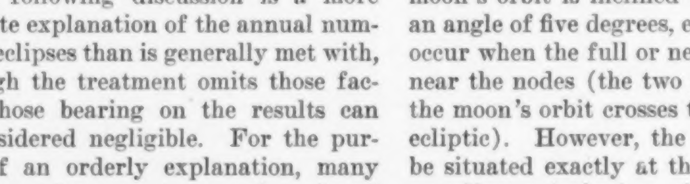


FIG. 1. MAXIMUM DISTANCE EARTH'S SHADOW CAN BE FROM NODE

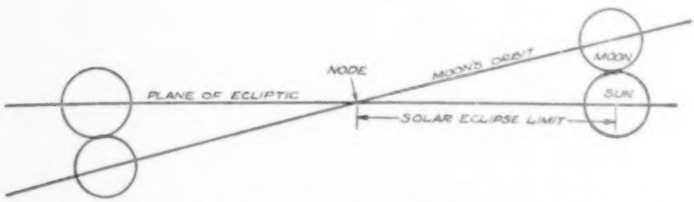


FIG. 2. MAXIMUM DISTANCE AT WHICH SUN CAN BE FROM NODE

positions, causing a variation in the angular dimensions of the sun and moon. The major solar limits are 18° 31′, and the minor, 15° 21′. For the moon the range is from 12° 15′ to 9° 30′. It is noticed that the solar limits are about fifty per cent. greater than the lunar limits. This can be seen from Fig. 3, where the diameters of the cone of light, whose elements are tangent to the sun and earth, into which the moon must move to cause eclipses, plus the moon's diameter, are in the ratio of 3 to 2.

Whenever the sun crosses one of the nodes of the moon's orbit, it will be within the eclipse limits and an eclipse season occurs. It is clear that this must happen twice a year. Further, since the moon's nodes make a complete regression in a little over 19 years, the sun crosses the same node a little earlier each year, the period from node to node being 346.62 days. This period is the eclipse year. Should the sun cross the node early enough so that the first eclipse season falls in January, then two eclipse seasons and part of a third season will occur in a calendar year, since the eclipse year is shorter than the latter.

The minimum solar eclipse limits are 15° 21′. Twice that interval is greater than the sun's motion in a synodic month, as the sun moves through the sky at a degree a day. The synodic month is the time between two successive occurrences of the phase of the moon, and is 29½ days. Therefore in an eclipse season the sun cannot pass through the limits under a synodic month and avoid a new moon in the region of the nodes. Consequently, the sun must be eclipsed at least once during each season, yielding a minimum of two solar eclipses annually.

If a solar eclipse occurs early enough in the eclipse season, the moon will overtake the sun again, still within the eclipse limits, causing a second solar eclipse in the one season. From this it can be seen that the moon must be full half way between the two solar eclipse positions, resulting in a lunar eclipse in the same season. An additional fact becomes evident. Since the two solar eclipses in this situation must occur at the extremities of the eclipse limits, they will always be partial eclipses, whereas the full moon between them will be at or very close to the node and hence will always be totally eclipsed.

As the major lunar limit is 12° 15′,

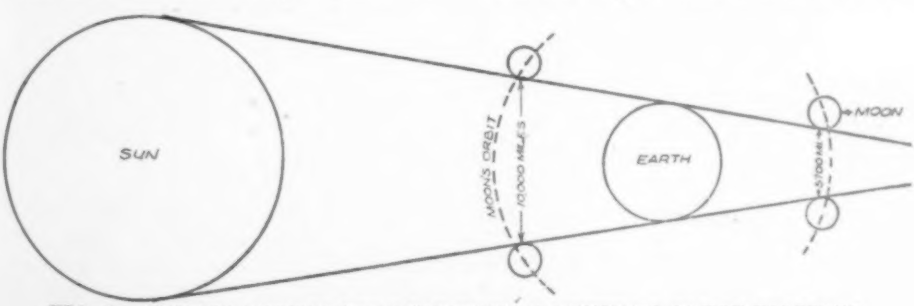


FIG. 3. CONE OF LIGHT INTO WHICH MOON MOVES TO CAUSE ECLIPSES

twice that is less than a synodic month. Thus the sun can move through the limits without once encountering a full moon. As a result a lunar eclipse need not take place at any eclipse season of the year.

For the five: two eclipse ratio to exist, three eclipses must occur in each of the first two seasons, and one solar eclipse in the third season of the same calendar year (or the reverse of this arrangement). If the sun is eclipsed 17 days and the moon 2 days before the sun passes a node, then the sun will again be eclipsed 12 days after that node, and in the second eclipse season of that year a solar eclipse will occur 13 days before the node, and lunar and solar eclipses will occur 1 and 16 days respectively after the node is passed. Since 12 synodic months are equal to 354 days, it is readily seen that the sun will be eclipsed for the last time nine days before the node of the third season, yielding seven eclipses in all. These time intervals may only vary by a couple of days, and still allow three eclipses in each of two successive seasons.

To show that 8 eclipses are not possible in a calendar year we may consider the following situation: the sun is eclipsed as early as January 1st. Then from the conditions given the third node is passed 363 days later (17 plus 346, the eclipse year). This leaves two days to the end of the year. Consequently, the full moon previous to this is before the lunar season, while the full moon after, although it is eclipsed, is in the next calendar year. Therefore eight eclipses may occur in three successive seasons, but only seven can occur as a maximum in a year.

To obtain the four: three ratio, the eclipse seasons must merely occur a bit earlier, so that the first solar eclipse which we considered on Jan. 1st, falls in the previous year, and the lunar eclipse which was missed at the end of the year, falls in the present year, giving three lunar and four solar eclipses.

With the five: two ratio, the sequence of eclipse dates as a whole has a range of 11 days, resulting from the 11 days between the last eclipse and the end of the year. In the second case the intervals as previously defined may vary by approximately 5 days since the first solar eclipse need no longer exist to get seven, in addition to the 11-day range of the sequence as a whole.

Before concluding we may examine actual examples of the cases which have been developed.

1935—the five: two ratio

Jan. 5—Partial eclipse of sun
Jan. 19—Total eclipse of moon
Feb. 3—Partial eclipse of sun

June 30—Partial eclipse of sun
July 16—Total eclipse of moon
July 30—Partial eclipse of sun

Dec. 25—Annular eclipse of sun

1917—four: three ratio

Jan. 8—Total eclipse of moon
Jan. 23—Partial eclipse of sun

June 19—Partial eclipse of sun
July 5—Total eclipse of moon
July 19—Partial eclipse of sun

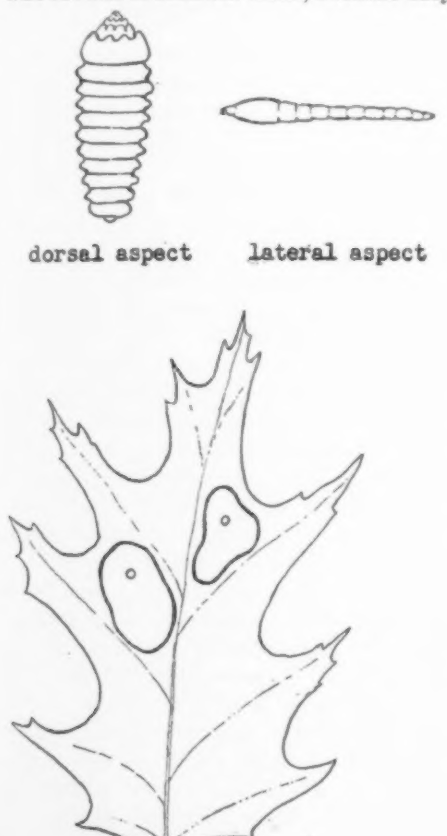
Dec. 14—Annular eclipse of sun
Dec. 28—Total eclipse of moon

LEAF-MINING INSECTS

By Dr. SIBYL A. HAUSMAN
DEPARTMENT OF ZOOLOGY, CONNECTICUT COLLEGE

"There's never a leaf nor a blade too mean to be some happy creature's palace."—*Lowell.*

AMONG the most interesting of the plant-feeding insects are the so-called "leaf-miners." They are rarely seen, except by entomologists and ecologists who set out to look for them, because they are very small and inconspicuous. These tiny creatures are small worms, the larval stages of insects which are able to obtain plenty of food and a suitable lodging by living entirely between the upper and lower surface cells of leaves.

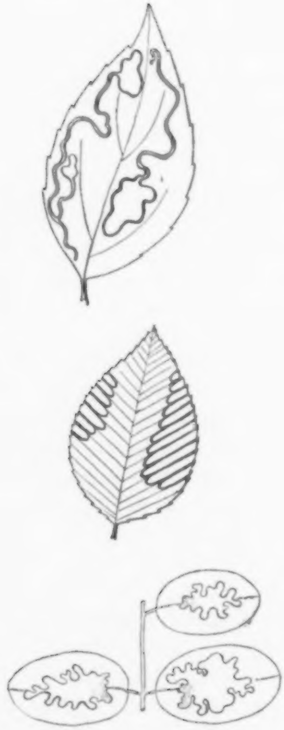


RED OAK LEAF-MINER AND ITS WORK
ABOVE: DORSAL AND LATERAL ASPECT OF THE LARVA. BELOW: MINE OF RED OAK MINER.

Certain members of the *Lepidoptera, Coleoptera, Hymenoptera* and *Diptera* insect orders spend their larval life within the leaf tissues, feeding on either the palisade or spongy parenchyma cells where the chlorophyll is located, well protected and concealed by the thin, colorless cells of the upper and lower epidermis.

The larvae usually enter leaves through the under surface and eat their way along into the green cells, leaving behind them various patterns which appear as transparent mines in a green leaf. These mines are fairly obvious to the casual observer and may be well known as pests to greenhouse workers and vegetable growers when they affect a large percentage of the foliage. The forms of these mines or tunnels, and the leaves of the kind of plant where they occur, are both characteristic of a given species. Often the mines are obscured by the accumulation of dark particles of waste material, known as frass, but some species keep their mines clean by distributing the frass in separate pockets. This habit is also characteristic of the kind of miner.

Mines in leaves offer considerable variety in styles. Some of them are straight or linear, snake-like or sepentine, blotch, linear blotch, trumpet and digitate. Mines may also be classified as to the depths to which the miners penetrate. A full mine is one in which the larva eats out both palisade and spongy



THREE MINE PATTERNS
ABOVE: SERPENTINE MINE. CENTER: WORK OF SCOTCH ELM LEAF-MINER. BELOW: MINE OF LOCUST LEAF-MINER.

parenchyma cells. Others mine only in the palisade layer, as, for example, the black locust leaf-miner.

Ecologically, the miners themselves may be grouped into two types, the *Diptera,* or flies, and the others, certain beetles, sawflies, wasps and moth and butterfly larvae. The *Diptera* larvae are cylindrical and tapering, with mouth parts adapted for tearing away and rupturing the cells. Others are streamlined and flattened dorsoventrally, with wedge-shaped heads and mandibles in front which work like shearing organs. Other adaptations are the absence of legs and spines and the reduction of eyes and antennae.

One of the best known of the leaf-miners can almost always be found in the leaves of the common locust tree. This is the work of the digitate Lepidopterous leaf-miner, *Parcetopa robiniella.* This mine typically extends along the mid-rib and spreads out on either side. The frass is packed away in one end, leaving the rest of the mine clean. When fully grown, the miner leaves the mine and spins a cocoon in a fold of a leaf or in a crevice in the bark. By holding a mine up toward the light, the frass and tiny larva can be observed inside, or they can be seen by gently tearing off the loose, thin epidermal cells.

In leaves of the well-known jewel weed, or "touch-me-not," which grows in moist woodlands, is often found the serpentine mine of a dipterous leaf-miner, *Agromyza borealis.* This mine is linear, winding and thread-like, ending in a large blotch. Dark specks of frass form a line down the center.

Of the coleopterous miners, one of the easiest to find is the work of the red oak miner, *Brachys ovata.* This is a rather conspicuous brownish mine on an interspace of the leaf. When the mine is old, or in pressed specimens, a flat, scale-like egg is visible on the surface, as a shiny, round speck. The larva passes the winter in the mine in fallen leaves, the pupa being formed in late May. The adult beetle emerges in about seven days.

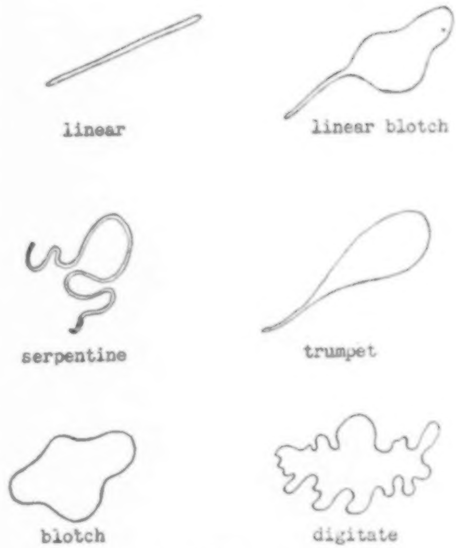
One of the *Hymenoptera,* a sawfly, is of particular importance economically because of the injury to leaves of the Scotch elm. In some localities, the damage done is so severe that every leaf is dry and brown and the tree has the appearance of being dead. These larvae often mine out the leaves completely between the veins, working during the months of May and June. Injury to the trees is completed by the end of June when the larvae leave their mines and winter over in cocoons in the soil. They pass through six instars, finally becoming flattened, pure white worms with a brown

head capsule vertical to the plane of the body. Pupation occurs in late April after the transformation of the larvae.

Many of the miners are of economic importance because of the damage done to shade and ornamental trees or to plants the leaves of which are used for food. Mining not only weakens the foliage, and hence the entire plant, but also serves as points where disease and decay may start. Leaves of vegetables are made unsalable and unattractive by the mined-out areas. Leaf-miners on marketable crops such as spinach, beets and Swiss chard are hard to control because they are so well protected. Spraying with nicotine sulfate, "Black Leaf 40," has met with partial success.

The leaf-mining larvae are truly fascinating to examine under a binocular microscope. Their remarkable adaptations in form and structure to the narrow limits of their environment, together with the types of these environments, which they fashion by means of highly adapted mouth parts, are extremely interesting.

Life histories of these insects offer attractive problems for ecologists and field biologists, and can be studied by placing the miners with their leaves in easily constructed containers. Such rearing



TYPICAL MINES

chambers can be made by cutting a hole in the center of a cover of a small, tight carton and fitting the open end of a glass vial in the opening. A rim of cotton may be placed between the opening and the vial to serve as a wedge and to provide for air.

The mines within the leaves can be kept indefinitely by pressing and covering with Cellophane.

WRITTEN RECORDS OF FOREST SUCCESSION[1]

By ELIZABETH CHAVANNES
UNIVERSITY OF WISCONSIN

OCCASIONALLY the ecologist is able to augment his ideas of plant succession with evidence taken from sources which are less fashionable than the quadrat and fossil pollen. Such an opportunity is found in the written records left by man where one may read a part of the story of the encroachment of forest upon the prairies of southern Wisconsin.

In place names, surveyors' maps and notes, and in such documents as letters, journals, and military reports, the nature of the landscape has been described in greater or lesser detail for more than a hundred and fifty years. The recency of these records of change in the prairie-woods balance in the southern part of Wisconsin does not detract from their value. Rather it enhances them as a sort of postscript to evidence of plant migrations in post-glacial time.

All plants were forced to retreat before the last advance of glacial ice which extended into Ohio, Indiana, Illinois, Wisconsin and Iowa. A narrow belt of tundra and conifers thrived at the edge of the glacier; but in the warm, fairly dry climate they gave way rapidly to xerophytic prairie plants on the south and west, and to mesophytic woods on the east.

As the glacier receded, the plants followed in its wake. At the same time that an arid post-glacial climate hindered formation of an extensive coniferous belt and slowed the advance of the deciduous forest, it helped the prairie establish itself. This latter movement culminated in the so-called "prairie peninsula" formed across Illinois, Indiana, southern Wisconsin and Michigan, and Ohio, its eastern limits now marked by relic colonies.

The first advance of the mesophytic forest and retreat of the prairie was begun in later post-glacial times after a climatic change, apparently in the direction of increased rainfall with winter as well as summer rains. The forest continued its westward advance from the Ice Age stronghold in the Appalachians until it extended to and perhaps beyond the Mississippi River and developed considerably in both area and density.

Once again the balance was thrown in favor of the prairie, and in those states of the "prairie peninsula" there occurred a second advance which developed certain characteristic elements of the prairie and woods floras. Prairies stretched over the moraines and outwash plains, and along river bluffs and ridges in the Driftless Area, that unglaciated portion of southwestern Wisconsin extending also into the adjoining states.

FIG. 1. EASTERN EXTENSION OF THE PRAIRIE.
SINCE THE RETREAT OF GLACIAL ICE. (MODIFIED AFTER TRANSEAU, AND FENNEMAN.)

[1] The greater part of this work was done while on a grant from the Wisconsin Alumni Research Foundation during the summer of 1938.

The prairies were spotted by isolated trees, or by scattered groves. Lakes and main water courses were fringed with woods of oak, hickory, basswood and maple, rich toward the east, thin in the west and south. A part of the wooded country lay in oak openings where spreading open-grown trees were underlain by prairie, rather than by forest litter.

In such a condition of mixed floral elements the woods could not advance as a single unit. Depending on whether the invading plants spread out from a prairie grove or into and through a relic colony isolated in the woods, the movement was centrifugal or centripetal. Despite strong tendencies toward encroachment, a balance slightly in favor of the prairie seems to have been maintained in most of southern Wisconsin until the nineteenth century when the culture of the white man was introduced.

Of the written records man has left, the three aforementioned classes all suggest that a substantial invasion of prairie area by woods has occurred within the limits of historical time. The significance of place names lies in the fact that when the pioneers migrated into a vast strange country they often turned to nature for their names. That the Indian had earlier done the same thing is shown in the name "Muscoda, place destitute of trees."

Prairie names stretch across the state

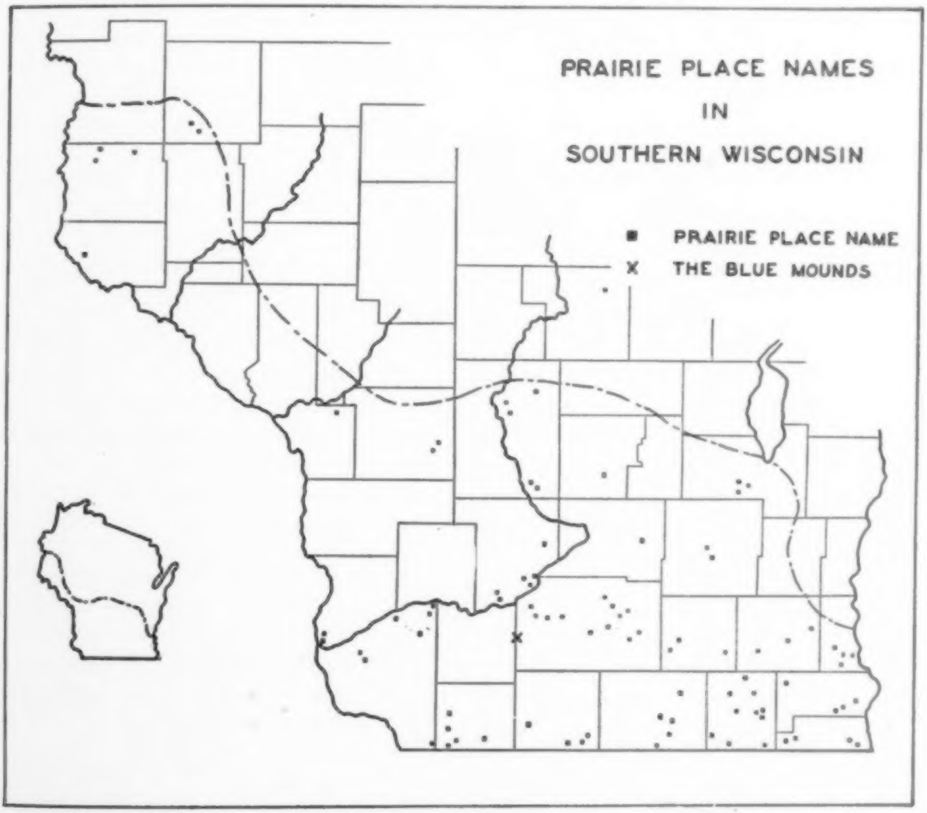


FIG. 2. DISTRIBUTION OF PRAIRIE PLACE NAMES IN SOUTHERN WISCONSIN
DOTTED LINE INDICATES HYPOTHETICAL BOUNDARY BELOW WHICH LAY NEARLY ALL WISCONSIN'S PRAIRIE AT THE TIME THE STATE WAS SETTLED.

from Lake Michigan to the Mississippi River: Pleasant Prairie, La Prairie, Sun Prairie, Prairie du Sac, Star Prairie. Post office names are supplemented by an abundance of colloquial names which persist locally, such as Bigfoot Prairie, Gardner's Prairie, Caldwell's Prairie. Not only was the fact of prairie recorded, but often size and shape, as in Heart Prairie and Twenty-Mile Prairie.

The town of Burr Oak suggests the presence of isolated trees in tracts of prairie. Other indicators of prairie are scattered groves, surprisingly abundant judging from the many names: Oak, Emerald, Union, Patch, Allen's and Gratiot's Groves, and a host of others. Such names as Deer Park perpetuate the oak opening, a type of tree-dotted prairie, characteristic of wooded areas and commonly described by a reference to English park scenery.

Names of a Richwood, Glenwood, Woodland type appear frequently, as do several Forest townships in the north and east. Scrub vegetation characteristic of areas undergoing encroachment is described in Hazel Green, a village name referring not to a pioneer's sweetheart, but to a condition commonly found in burned-over woodland. After ground cover and trees were destroyed by recurrent prairie fires, hazel brush sprang up thickly, persisting through the fires by virtue of a sturdy root system, flourishing as a scrub between destructions.

Out of this welter of names comes the realization that below a line running diagonally across the state from the southeast lake-shore corner, northwest to the counties beyond the end of the Mississippi River lay nearly all the prairie Wisconsin possessed at the incidence of historical record.

This general picture can be made a great deal more specific by the notes written as the area was surveyed, and by the maps prepared from the notes. It was the custom for the surveyors to walk the section lines, which run at one mile intervals, and to record the types of vegetation through which they passed, as well as the number and size of noteworthy trees. Thus the vegetation of a vast amount of country was systematically charted, for the most part by competent sober men.

Corollaries of the notes are the maps based upon them. As nearly as one can tell, they were drawn directly from the notes, frequently not by the surveyors themselves and usually not for some years after the actual survey. They delimit woods and prairie in such a fashion that the result corroborates the distribution which place names indicate. Reports of copses, thickets and scrubs of hazel and oak confirm the presence of an encroachment hindered by the prairie fires. The first statement concerning the proportions of prairie and forest in southwestern Wisconsin seems to be that of Chandler in 1829 on his map of the lead-mining region. He describes the area as nine tenths prairie with the one tenth woodland distributed in groves.

Far and away the most abundant source of material is found in that omnibus class of letters, journals, histories, commercial pamphlets and the notes of military expeditions. It is the best in point of quantity, often in quality, and certainly in point of time since it began in 1670 or earlier and continued to date. Nearly all explorers kept notes assiduously, while the reports of most surveyors and military men were augmented by personal journals of a more general nature. These were far more restrained and accurate than the pamphlets, advertisements and maps which naturally accompanied the exploitation of the rich West. The best material of all came from observant imigrants who were often amateur botanists and naturalists. Their knowledge made for accuracy, and from them is obtained the most complete and satisfying idea of prairie and forest relationships.

The prairie docks and cone flowers,

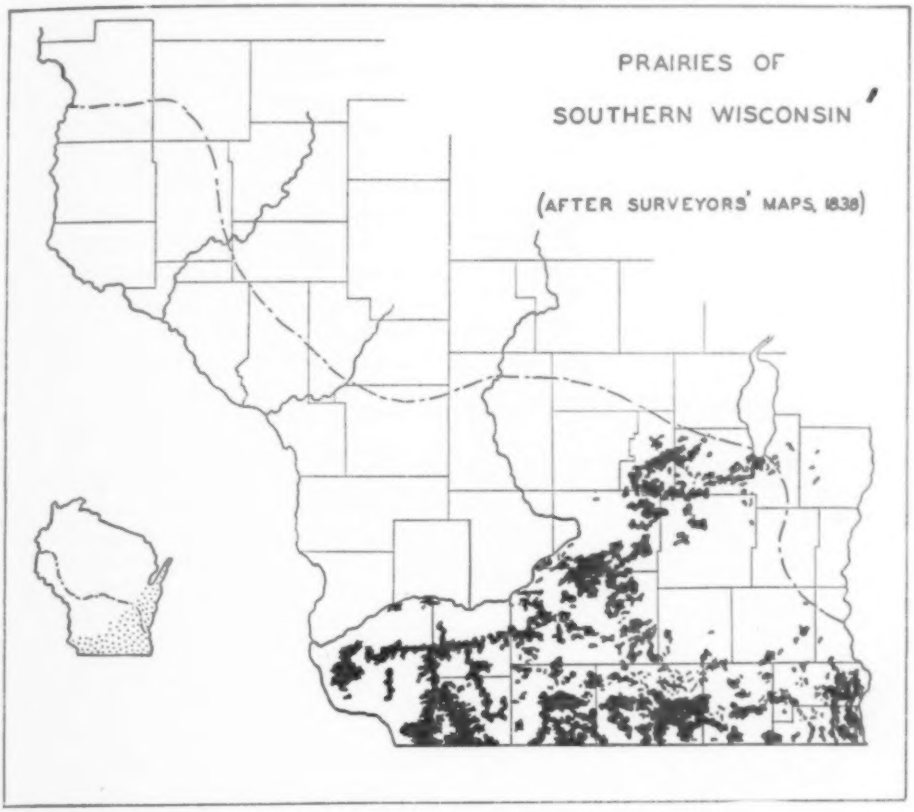


FIG. 3. PRAIRIES RECORDED BY SURVEYORS
EXTENT AND DISTRIBUTION OF PRAIRIE IN THAT PART OF WISCONSIN, INDICATED BY STIPPLING, WHICH WAS INCLUDED IN THE SURVEYORS' MAPS OF 1838.

blazing stars and goldenrods were referred to only less often than the grasses which formed such an overtowering part of the midsummer landscape. "A sea of grass" was the universal metaphor.

The constitution of the woods depended on the section of the state. Along the lake shore the forest was dense with hard and soft maple, beech, red and white cedar, white birch, two hickories, two walnuts, two pines, tamarack, sycamore, hackberry, poplar, balm of Gilead, aspen, basswood, common and slippery elms, and red, white, burr and pin oaks. On the other hand, farther west a characteristic woods flora included oak, ash, elm, maple, basswood, hickory, butternut, black walnut, plum, crab, grape and the like. Often the woods' floor was so open that it was recommended for horse racing and carriage driving, while the lack of underbrush offered "no impediment to the chase (of deer)." In the northeast "the land inclines to a rolling east, and is covered with red, white & black oak and the most beautiful groves of sugar maples, without any underbrush."

The rapidity with which woods grew under protection was common knowledge, for though the prairie might be treeless when settled, trees set out for house protection and ornament or for woodlots grew thriftily, almost without exception. A striking example of this is described in the first annual report of the Wiscon-

sin Geological Survey on a farm where grew "dense groves of young trees from six to ten inches in diameter, where, twenty-five years ago, not a single shrub could be found larger than a riding-whip." This same process in various localities served to strengthen the conviction that if the prairies were given proper protection from fires for a few years, every farm upon them would have an adequate supply of timber. The source of the new timber would lie in the seeds, roots and stumps sending up new growth after the inhibiting or destructive forces of the prairie fires were removed.

Apparently this phenomenon was the chief cause of a 60 per cent. decrease in the prairie area of southwestern Wisconsin, which occurred between 1829 when Chandler marked it as nine tenths prairie, and 1854 when the Geological Survey reported it was only one third prairie, broken in part by groves and oak openings.

But has there really been a marked increase in wooded territory at the expense of the prairie within historical time? Undoubtedly so, but it has not been accomplished by the natural processes of invasion alone. Before the advent of explorers, regiments and settlers, the successional processes between forest and prairie maintained themselves naturally, and the success of the slowly encroaching woodland seemed to depend chiefly on recurrent prairie fires set by the Indians. However, the men who preempted southern Wisconsin put an end to the fires and disturbed the natural prairie-woods balance. With the cessation of fires there was a tremendous acceleration of woodland growth in those areas where fence lines furnished an early protection. This prodigal increase in wooded area, aside from the plantings that thrived around farm houses and along roadsides, was soon limited to woodlots and windbreaks, but not before the wooded aspect of the country had become quite pronounced. Then, too, man's occupation soon destroyed the prairies that were open to invasion. It was not long before there was no spot where one could be out of sight of trees.

A hundred and sixty years ago Jonathan Carver climbed one of three limestone outliers in southern Wisconsin known as Blue Mounds and recorded that he "had an extensive view of the country (where) for many miles nothing was to be seen but lesser mountains, which appeared at a distance like haycocks, they being free from trees." Scarcely seventy years ago, a Mrs. John Kinzie passed by the Blue Mounds on the way to Chicago and lamented that it was a country without landmarks, where "one elevation is so exactly like another, that if you lose your trail, there is almost as little hope of regaining it as of finding a pathway in the midst of the ocean." To-day one looks from the Blue Mounds over a sea of green trees broken by fields and pastures and probably never thinks that once it was all a treeless prairie, save for short deep valleys running north to the Wisconsin River.

However, the country is made picturesque by evidences of the encroachment of the woodlands. Wide-spreading burr oaks stand alone in the middle of cornfields. Woods in winter show straight, high-branched trees stretching up between old oaks whose branches start six, ten, twenty inches from the ground, telling of growth in the open, unhampered by surrounding trees.

Encroachment of the forest in southern Wisconsin to-day is a limited process, pushed to fence corners and the relic prairies on bluffs too steep for pasturing or plowing. The landscape, rich in oak and hickory, maple and linden, is indeed a far cry to the time when the people who came to Wisconsin found one of the greatest drawbacks to travel was the lack of sufficient wood to build a campfire.

BOOKS ON SCIENCE FOR LAYMEN

ROCKS FOR LAYMEN[1]

THIS book is a new member of the natural history series and brings to an even dozen the series designed to enlighten the interested reader concerning the forms of nature with which he is in daily contact. This is the first book to deal with inanimate objects, and all persons working in geology will be pleased to see the well-known set expanded to include this science.

Geology and the story of its processes, as shown by rocks, does not lend itself to the same type of description as do some of the other natural sciences, perhaps because no readable accounts of life habits can be given. Hence, it is not exactly proper to compare this volume with others of the set; yet being one, it must be considered as intended to cover geology from the same approach as the other texts have their respective subjects.

The first five chapters of this text do not read as smoothly as the last fifteen chapters, the reason being that a considerable amount of factual information, such as physical properties of minerals, as well as types and varieties of igneous rocks, etc., is included. However, the incorporation of this material is necessary and rightly belongs to the first portion of the text. It is apparent to a reader that the authors are much more at ease with the subject-matter in the last chapters than in the first five.

The book is well illustrated and the plates for the most part are very good. One of the four color plates is excellent; the others are not outstanding. In almost every case it is possible for a person familiar with the subject to identify from the illustrations the mineral, rock or physical feature without referring to the legends. This is certainly something which can not be said regarding many texts dealing with rocks and minerals.

[1] *The Rock Book*. C. L. Fenton and M. A. Fenton. Illustrated. xx + 357 pp. $6.00. September, 1940. Doubleday, Doran and Company.

The reader will find it most annoying to be constantly leafing to another portion of the book to see the illustration of the subject described on the page being read. Text and illustrations could not have been more perfectly separated had a definite effort been made to keep them apart.

Since it is necessary for authors of books of this nature to use concise outlines for complicated geological processes, they can not be expected to please all readers by their statements of these complex problems. This reviewer does not think it important to cite cases in this book where perhaps a slightly different statement of processes could have been made. To do so would be quibbling about details. A surprisingly large number of geological terms has been covered, and to do this in 348 pages naturally it has to briefly dispose of most topics.

This reviewer believes it might have proven more desirable had the authors taken a subject more restricted in scope. In fact, it is thought the authors erred in selecting the title for the book; also in attempting to cover such a wide and varied field in one volume.

The publishers of this series once thought it desirable to issue two volumes on the same class, namely, one treating butterflies and the other moths. These two insects are frequently confused by most people and only the specialist can distinguish them. Hence if two separate texts were necessary in that case the title of "Rocks" would certainly warrant that two volumes should be prepared.

In "The Rock Book" the authors have not only briefly discussed most of the major types of rock, but have covered many features of physical geology as well and have included a chapter on meteorites and one on ores. A worthy improvement could have been made if the subject-matter had been expanded and discussed in two volumes. Perhaps, then, a few

more chapters could be devoted to ores. As it is now, the ores of the different elements are mentioned but not properly developed and this might be of greater interest to the readers than some of the included descriptions of rather unimportant rock types. A definitely more readable and authoritative account could then be prepared which would make this book of value to the student of geology, as well as to the amateur collector and to the more serious-minded traveler for whom this work seems to be prepared.

This reviewer does not wish to convey the impression that his opinion is entirely uncomplimentary. There may be good reasons why so many geological terms should be developed and discussed in one volume. For example, persons knowing little of geology can find in this book an informative account of things they see in the field.

The layman who is interested in better understanding the country over which he travels, likewise the amateur collector, will no doubt find this a good book for his library and one to which he will frequently refer. It is assumed, however, that the text was written for amateurs. For them it is a good field guide. It is hoped that all persons making rock and mineral collections will pay special attention to the authors' concluding chapter where good advice is offered as to both the purpose of collections as well as the manner in which records should be kept.

E. P. HENDERSON

THEY LET THEIR LIGHT SHINE[1]

FROM ancient times light produced by living organisms has been thought of as something mysterious. Many have studied it and much has been written, but it remained for Dr. Harvey, who has been a student in this field for many years, to bring together in one book the results of studies which deal with all angles of the problem. This book, "Living Light," first discusses the problem of cold light in general, a discussion which all interested in the topic should read. Next is brought together information about those organisms which have the power of producing light, and there are many more of them than most persons realize. At least eleven different phyla have some forms which are capable of luminescence. Not all do so in the same way, and various types of organs are found.

The types of luminescence are classified according to origins and their characteristics are described. Special chapters are devoted to the chemistry and physiology of luminescence and the works of many authorities carefully evaluated. The chapter on the physical nature of animal light is especially interesting, for in it are discussed the means of light measurement and the amount of energy involved. Is it true that the light of a firefly is much more efficient than that of an electric light? How is this determined? These questions and many others are answered.

All in all the book is a very valuable contribution, for in it are brought together the results of the researches of many workers in many fields, each approaching the problem from the special angle of his interest. The results are evaluated and coordinated so that they are available to any one who is interested. One may know what has been done, what has been attempted and what needs to be done. Dr. Harvey has demonstrated that the physical and chemical fields can contribute much to that of biology, always providing that the biologist has the ability to use them. Dr. Harvey has this ability.

D. B. YOUNG

[1] *Living Light.* E. Newton Harvey. Illustrated. 266 pp. 1940. Princeton University Press.

SEA ANIMALS—TOO WONDERFUL[1]

PERHAPS it is not fair for one trained in science to review a book in his subject which is written purely as a popular

[1] *Wonder Creatures of the Sea.* A. H. Verrill. Illustrated. xix + 272 pp. $3.00. May, 1940. Appleton-Century Company.

treatise. However, the general public should be entitled to the opinion of one who is deemed capable of passing upon such a work, verifying the authenticity of the material contained therein.

It is deplorable that more popular scientific accounts are not written by the scientists themselves. Science owes the general public this service, for what scientist is not supported directly or indirectly by the general public? It would also be good for the scientist to be required to put forth an account of his field in simple language.

A. Hyatt Verrill in his "Wonder Creatures of the Sea" follows the frequent procedure of writers of popular books of taking scientific facts and enlarging upon them until a goodly portion of the book becomes fancy.

The author also follows the general trend of such writers of interjecting into the text the human element to the extent that some of the more lowly forms of life, those without even any centralization of the nervous system, experience such sensations as stomach ache and hypnotic influence.

There is little reference to size in the book. One might easily form the opinion that copepods, sea-spiders (pycnogonids) and many of the crabs are of about equal size.

Although the book contains many interesting facts about marine animals, how is the reading public to know where fact ends and fancy begins? The book may be interesting reading, but it can scarcely be recommended from an educational point of view.

G. E. MacGinitie

EXERCISE FOR HEALTH[1]

Exercise, like so many other things, can be used with benefit or abused with resultant harm. The value of exercise, in both the positive and the negative sense, depends upon the degree of good sense with which it is taken. This, in turn, must be based upon knowledge concerning the effects of exercise. At this time when the maintenance of physical fitness becomes increasingly an obligation to the commonwealth, it is particularly fitting that there should appear a thoroughly revised edition of a text on the physiology of exercise. Different types of exercise are well analyzed and the comprehensive discussions of the effects of exertion upon the circulatory and respiratory apparatus are sound. The physiology of muscular action is adequately presented.

The effects of special types of muscular exercise upon bodily functions are considered in relation to age. The special questions arising with adolescents and with people over forty years of age are discussed separately. The advice regarding limitations imposed by aging is good and should be heeded especially by two groups of middle-aged men: Those who refuse to admit that senescence has depreciated their capacity for violent games and who insist upon intense activity after long periods of sedentary softening, and secondly, those who use their age as an excuse for indolence. Either extreme is unwise. There is a refreshing lack of prejudice on the part of the authors; so many volumes on sports or exercise are woefully asymmetric in their viewpoint.

The book is particularly recommended to all those who have active responsibilities in connection with exercise or sports, such as educators, student health physicians, industrial hygienists, gymnasium directors and instructors, and officers responsible for the training of military personnel, as well as those whose interests in exercise are more personal. It will not interest the Big Muscle Men of the Health Club type; it is too sane. The authors have succeeded in presenting much valuable information in a highly digestible form.

Edward J. Stieglitz

[1] *The Physiology of Exercise.* James H. McCurdy and Leonard A. Larson. Third edition, 349 pp. 1939. Lea and Febiger.

SIR CHANDRASEKHARA VENKATA RAMAN

THE PROGRESS OF SCIENCE

FRANKLIN MEDALISTS FOR 1941

THE Franklin Institute, in its annual award of medals, bestowed its highest honor, the Franklin Medal, this year upon two distinguished scientists, one foreign and the other American. The foreign recipient was Sir Chandrasekhara Venkata Raman, the eminent Indian physicist and Nobel prize winner in physics for 1930, who is most famous as the discoverer of "the Raman effect." But the award of the Franklin Medal was not made for any single experimental result of outstanding importance. The citation states that it was "in recognition of his many brilliant contributions to physical science and of his leadership in the renaissance of scientific work and scientific education that has occurred in India during the last thirty years."

Thirty years ago a scientific career offered little inducement to a young Indian, so that Raman was forced by circumstances rather than by tastes to enter the government service. While serving in the Indian Finance Department he devoted his leisure to the pursuit of scientific interests, and during the years between 1907 and 1917 he contributed thirty original papers to British scientific journals.

These papers established his reputation as an original thinker and, in 1917, when the Palit professorship of physics in the University of Calcutta fell vacant, the chair was offered to him. Since he was appointed to this position, Raman and his collaborators have contributed more than six hundred titles to the literature of sound, musical instruments, ultra-sonics, diffraction, meteorological and colloid optics, photo-elasticity, x-ray diffraction, electro- and magneto-optics, and dielectrics.

In 1921 Raman began work upon the scattering of light, and within three years had attained such eminence in the field that he was invited to open a symposium on the scattering of light at the Toronto meeting of the British Association. Four years later his researches into this subject led to the discovery of the phenomenon that bears his name—the Raman Effect.

The effect is described by Kastler[1] as follows: "When a homogeneous and chemically defined substance is irradiated with monochromatic light, part of the energy of light is subtracted from the incidental pencil and diffused by the molecules. The most important part of the scattered light is that possessing the same frequency as the incidental radiation (Rayleigh line), but a definite fraction of the energy of light which is scattered by the molecules undergoes a change of frequency (Raman Effect)."

The first studies of the effect were largely theoretical, representing attempts to fit the new phenomenon into theories of radiation and of the structure of matter. Later studies have utilized the phenomenon in the investigation of the constitution and structure of chemical compounds.

Raman's great ambition has been to make India a force in the scientific world. For the past twenty-five years all his talents have been dedicated toward that end. More than one hundred young scientists trained and inspired by him occupy strategic positions in the scientifical and educational life of India. Nearly every institution in India devoted to research and education in science has benefited by his influence and support. The brilliance of his researches, the international character of the recognition of his work, his success

[1] "The Raman Effect and Multiple Scattering of Light," by A. Kastler. "Jubilee Volume of Original Papers," Proceedings, Indian Academy of Sciences, November, 1938, p. 476.

MAJOR EDWIN H. ARMSTRONG

as a teacher, his ability and success in founding journals for the publication of scientific work in India, are among the factors which have profoundly influenced the progress of science in his native land.

The other Franklin Medal was awarded to Major Edwin H. Armstrong in recognition of his "pioneer work in Regeneration and the Oscillating Vacuum Tube Circuits, in the invention of the Superheterodyne Circuit, the Super-regenerator, and a system of Wide Swing Frequency Modulation, each an outstanding contribution to the communication art."

With the collaboration of the late Professor J. H. Morecroft, he applied the oscillograph to the investigation of the nature of the currents and voltages in the audion circuit. Upon finding alternating current components in the plate circuit, he reasoned that these could be augmented by tuning, which was a general technique in radio frequency circuits. Upon inserting a tuning coil in the plate circuit he discovered that the amplification was enormously improved and could be increased to the point where a continuous oscillation in the circuit was obtained.

Realizing the limitations of the tuned radio frequency receivers, Armstrong achieved a great forward stride in building a sensitive, stable, high-gain, low-frequency amplifier of fixed tuning, employing components and technique that were well known. He then, by using the heterodyne principle of Fessenden, converted the incoming high frequency signals to the relative low frequency to which his amplifier was tuned.

In 1922 Armstrong presented before the Institute of Radio Engineers a paper entitled "Some Recent Developments of Regenerative Circuits." This was the first publication of his super-regenerative method of reception. This paper describes methods by which the effective resistance of a regenerative circuit may be made periodically positive and negative, though predominantly positive. Oscillatory circuits consisting of inductance and capacitance have a certain amount of resistance—positive resistance. This is the reason why free electrical oscillations in such circuits are damped. When such a circuit is connected to a regenerative vacuum tube, the feeding-back of energy from the tube's output to its input circuit will effectively wipe out the positive resistance of the oscillatory circuit. When the resistance changes from positive to negative, due to the feeding-back of more and more energy, the circuit becomes self-oscillatory.

The fight of science against radio communication's greatest foe—"static"—began years ago. Many investigators gave it up in despair, arguing that, since the radio waves set up by electrical disturbances were of the same character as those from the transmitter, it was impossible for the receiver to differentiate between them and remain unresponsive to static while reproducing signals. Armstrong spent several years on this problem before he evolved the method that led to success. His triumph lay in transmitting and receiving a type of signal that possessed characteristics which differed from static—which is an amplitude-modulated impulsive wave.

Already this new method of radio communication has made possible the successful relaying by radio (not over wire lines) of broadcast programs through four or more stations linking New York city with various stations in New England. Such a multi-step relay system yields speech quality equal to or better than that furnished by the usual broadcasting toll wire service. The successful relaying of television pictures has also been conducted. F–M greatly improves the important factor of understandability in services such as police radio, aircraft and tank corps radio services, and it offers millions of listeners increased musical enjoyment. It has the features of a revolutionary improvement.

HENRY B. ALLEN,
Secretary and Director
THE FRANKLIN INSTITUTE

NATIONAL NUTRITION CONFERENCE FOR DEFENSE

AT President Roosevelt's request a conference of nine hundred delegates convened in Washington, D. C., the latter part of May to explore and define our nutritional problems, to assist in the formulation of a national nutrition policy and to map out recommendations for an immediate program of action. The importance of the nutritional status of the people in relation to our program of national defense was expressed in the President's message to the delegates, which is quoted here in part:

> . . . During these days of stress the health problems of the military and civilian population are inseparable. Total defense demands man power. The full energy of every American is necessary. Medical authorities recognize completely that efficiency and stamina depend on

proper food. Fighting men of our Armed Forces, workers in industry, the families of these workers, every man and woman in America, must have nourishing food. If people are undernourished, they can not be efficient in producing what we need in our unified drive for dynamic strength. . . .

The need for unified action on the nutritional front is evident in the face of such facts as the following: Dietary surveys made in the U. S. Bureau of Home Economics have shown that some 45 million persons in this country have diets which would be considered definitely inadequate even when measured by the most conservative standards; as many more persons have diets that rate only fair by the same standards. Intensive clinical investigations of nutritional status made by various agencies, and employing every appropriate measure known to science, have disclosed many cases of specific nutritional diseases. These diseases are due to the use of diets extremely low in one or more vitamins, or in certain minerals. Pellagra, beriberi, scurvy, rickets, keratitis and a number of other recently defined vitamin deficiency diseases, as well as anemia and tetany, all exist to some extent in the United States.

But far more numerous than the patients suffering from well-defined dietary deficiency diseases are the borderline cases—persons suffering from "hidden hunger" because they have lived for weeks, months or years on diets that are below the safety line. Chronic fatigue, nervous irritability, shifting aches and pains, certain kinds of digestive disturbances, bad teeth, lack of muscular vigor and many other below-par conditions interfere with efficiency and destroy the feeling of well-being.

The prevention and treatment of nutritional diseases and of borderline states of undernutrition are of major importance in making the country strong for defense. If America is to be well nourished, if nutritional deficiencies, major and minor, are to be wiped out, ways and means must be devised for every family and every individual to have a diet that measures up to accepted nutritive standards.

PRINCIPALS OF THE NUTRITION CONFERENCE
PAUL V. McNUTT, M. L. WILSON AND DR. RUSSELL M. WILDER.

These are briefly the problems faced by Mr. Paul V. McNutt, in his capacity as coordinator of health, welfare, nutrition, recreation and related activities in the Federal Office for Emergency Management. His advisory committee of government specialists, with M. L. Wilson, director of extension work in the Department of Agriculture, has been at work for many months assembling information and formulating preliminary plans for a program for nutrition in relation to national defense. Nutrition committees in practically every state have meanwhile been working on programs to meet local situations under the leadership of Dr. Helen S. Mitchell, director of nutrition for Mr. McNutt. When it came to setting up an action program for the entire country, it was realized that no federal group could do the job, and that coordination of state efforts was important. Thus the National Conference on Nutrition for Defense was called, with a number of representatives from each state and a number of government specialists. The conference was divided into nine specialized working sections, and each delegate was assigned to a specific section according to interests and background. The problems to be solved were given over to these sections for analysis. These sections functioned in the democratic way, with discussion from the floor led by chairmen who are authorities in their special fields.

In opening the first general session, Mr. McNutt as chairman outlined the great responsibility he was placing on the delegates, and made it clear that he wanted not oratory but an action platform. He summarized nutrition and welfare problems, and Dr. Russell M. Wilder, of the Mayo Clinic, followed with a strong emphasis on medical aspects. During the conference Vice-President Wallace set three special goals: wiping out deaths caused by dietary deficiencies; a great reduction in those diseases such as tuberculosis, towards which insufficient food predisposes; and making sure that every one in the United States has in his diet enough energy, enough bone, blood and muscle-building food, enough vitamins, to give that feeling of "health plus."

Representatives of various government departments concerned with the problems under consideration outlined the policies of their agencies as related to a national nutrition program. Outstanding authorities in the fields of nutrition and public health summarized recent findings that could be applied in working out recommendations.

A special committee on food and nutrition appointed last fall by the National Research Council, with Dr. Russell M. Wilder as chairman, had been assembling technical information which could serve as a basis for the formulation of policies. This committee presented to the conference a chart of recommended daily allowances for ten nutrients. These allowances are higher in vitamin content, especially in thiamin, nicotinic acid and riboflavin, than nutritive standards previously accepted. In presenting the chart to the conference, Dr. Wilder said: "If America is to have the healthy people we need in this national emergency, we must improve our diets so that they more nearly measure up to this new yardstick for nutrition." The new yardstick was adopted by the conference.

The recommendations for action programs were presented by the sectional chairman for the consideration of the total conference group and were summarized for presentation to President Roosevelt.

Every person professionally trained in medicine, public health, nutrition, dietetics, nursing, social service and all allied fields should be mobilized for nutrition-in-defense work in their own communities. Lay leaders should be trained to assist in the tremendous job of enlist-

SOME MEMBERS OF THE BOARD OF DIRECTORS OF THE NATIONAL SCIENCE FUND

PHOTOGRAPHED AT THE ORGANIZATION MEETING AT THE END OF APRIL. *Left to right:* DR. WILLIAM J. ROBBINS, DR. HARLOW SHAPLEY, DR. KARL T. COMPTON, DR. FRANK B. JEWETT, DR. ALBERT F. BLAKESLEE, DR. DOUGLAS JOHNSON AND DR. ROBERT A. MILLIKAN.

ing the interest of every citizen in his own nutritional status, and in emphasizing to the general public the importance of good nutrition in relation to health and to total defense.

An increased program of the Department of Agriculture's Surplus Marketing Administration will enable many families through the Food Stamp Plan and many needy school children through expansion of the free lunch program to be better nourished.

Increased opportunities for employment, more adequate housing facilities, stabilizing of prices for essential goods and services, were also discussed as practical means of putting across an all-American program for better health and vigor.

These are only a few of the challenges offered to the conference delegates to be relayed to groups back home who will work on a state, county or local level. The importance of coordinated effort of all existing agencies at all levels was emphasized and re-emphasized, in doing the job at hand—making Americans strong for defense.

ROWENA S. CARPENTER
BUREAU OF HOME ECONOMICS,
U. S. DEPARTMENT OF AGRICULTURE

THE NATIONAL SCIENCE FUND

THE National Science Fund was established by the National Academy of Sciences at its recent annual meeting for the primary purpose of providing an organization to which any person, foundation or corporation may entrust funds for the advancement of science with assurance that they will be used wisely and fruitfully. The new organization was launched after a three-year study of the present sources of financial support for fundamental researches in science by a committee of The National Academy of Sciences, under the chairmanship of Dr. Albert F. Blakeslee.

The National Academy of Sciences was incorporated in 1863 by an Act of Congress which was approved by President Lincoln. In accordance with the terms of its charter it has often responded to requests from the government for advice on scientific matters. In 1916 the academy greatly increased its ability to serve the government and the country by organizing the National Research Council at the request of President Wilson. Now it has extended the range of its activities still further by setting up the National Science Fund to receive and administer funds dedicated to the support of scientific research.

Direction of the new organization is vested in a board of directors consisting of four *ex-officio* members, seventeen elected members from the academy and twelve distinguished citizens who are not members of the academy. The members of the board are as follows:

Ex-officio members: Dr. Frank B. Jewett, president of the Academy, Dr. Jerome C. Hunsaker, treasurer of the Academy, Dr. Ross G. Harrison, chairman of the National Research Council, and Dr. Irving Langmuir, president of the American Association for the Advancement of Science.

Members from the Academy: Professor Roger Adams, Dr. James R. Angell, Dr. A. F. Blakeslee, President Isaiah Bowman, Professor Arthur H. Compton, President J. B. Conant, Professor Edwin G. Conklin, Dean L. P. Eisenhart, Dr. Herbert S. Gasser, Herbert C. Hoover, Professor E. O. Lawrence, Professor Frank R. Lillie, Dr. Robert A. Millikan, Dr. Alfred N. Richards, Dr. William J. Robbins, Dr. Harlow Shapley and Dr. G. H. Whipple.

Members of the board who are not members of the Academy: Winthrop W. Aldrich, chairman of the Board of Chase National Bank, James F. Bell, chairman of the Board of General Mills, Inc., Hon. John W. Davis, former Ambassador to Great Britain, Homer L. Ferguson, president of Newport News Shipbuilding and Drydock Company, Walter S. Gifford, president of American Telephone and Telegraph Company, Dr. Carlton J. H. Hayes, professor of history in Columbia University, Dr. Archibald MacLeish, librarian of the Congressional Library, Harvey S. Mudd, president of Cyprus Mines Corporation, Elihu Root, Jr., lawyer, Tom K. Smith, president of Boatmen's National Bank (St. Louis), Lewis L. Strauss, partner in Kuhn, Loeb and Co., and Harold H. Swift, vice-

SOME MEMBERS OF THE BOARD OF DIRECTORS OF THE NATIONAL SCIENCE FUND
PHOTOGRAPHED AT THE ORGANIZATION MEETING AT THE END OF APRIL. *Left to right:* DR. WILLIAM J. ROBBINS, DR. HARLOW SHAPLEY, DR. KARL T. COMPTON, DR. FRANK B. JEWETT, DR. ALBERT F. BLAKESLEE, DR. DOUGLAS JOHNSON AND DR. ROBERT A. MILLIKAN.

chairman of board of Swift and Company and chairman of board of trustees of the University of Chicago. Dr. William J. Robbins, director of the New York Botanical Garden, was designated acting chairman of the board.

Although the National Science Fund is empowered to receive and administer funds for the support of scientific research, it will not enter immediately on a "drive" for large sums. It will, instead, formulate basic principles and machinery of operation deserving of the confidence of great numbers of persons who will desire to contribute to the advancement of civilization through science.

There is a general impression that gifts in support of science and education in the United States are rapidly declining. As a matter of fact, such is not the case. All the thirty great foundations have been established since 1900 and fourteen of them since 1920. The Rackham Foundation, with an endowment of $12,500,000, was established as recently as 1933.

The purposes of these great foundations are to promote human welfare in various ways. For example, the stated purpose of the Rockefeller Foundation, established in 1913, is "to promote the well-being of mankind throughout the world." The Children's Foundation of Michigan, established by Senator James Couzens in 1929, was "to promote the health, welfare and happiness of the children of the state of Michigan and elsewhere in the world." The Duke Foundation of $40,000,000, established in 1924, was to promote "the needs of mankind along physical, mental and spiritual lines" in the South. The total assets of these great foundations amount to about $700,000,000, and the amounts expended by them to date for the purposes for which they were organized are approximately $900,000,000. In addition there have been hundreds of large gifts every year in support of universities, colleges, libraries and other institutions organized for public good. In view of these great and continuing gifts, the National Science Fund will almost certainly receive generous support.

F. R. M.

DEMONSTRATION OF THE EFFECT OF RADIATION ON ORGANISMS AT THE SMITHSONIAN INSTITUTION

On his tour of the Great Hall of the Smithsonian Institution, the visitor will see, in the fourth alcove, a cross section of the activities of the Division of Radiation and Organisms. This division gives practically its entire time to the study of radiation as it affects living things.

The central motif is seen on the middle panel (Fig. 1). Here is shown a diagram two meters long of the great electromagnetic spectrum extending from the short cosmic rays, through the x-rays and ultraviolet to the visible, then into the infrared and the radio waves. The visible, or central, portion is enlarged and shown below the diagram in the form of an actual spectrum from a grating.

In the panel to the visitor's right are exhibits which illustrate the effects of light on plants. The first is a working schematic diagram of a plant (right side of Fig. 4). Here is illustrated the movement of water through the plant stem from root to leaf, where it evaporates. This loss of water is technically called "transpiration." Another leaf illustrates respiration, in which small particles of "carbon dioxide" are shown escaping from the plant and small particles of "oxygen" entering. A third leaf illustrates photosynthesis, that fundamental process taking place in green plants whereby carbon dioxide is absorbed from the air in the presence of light and is converted into sugar and starch. The visitor may press a button and see the leaf absorb "carbon dioxide"

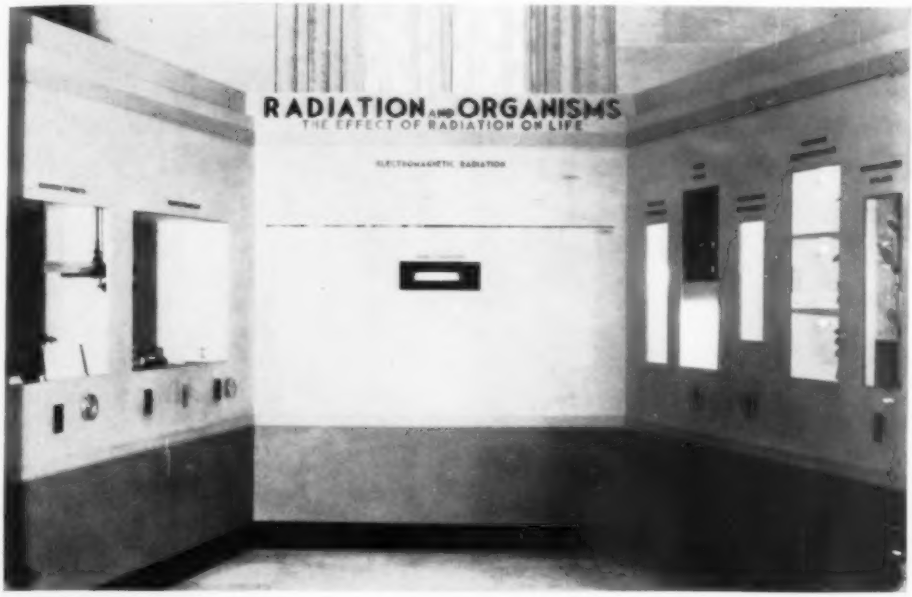


FIG. 1. EXPERIMENTAL EXHIBITS OF THE DIVISION OF RADIATION AND ORGANISMS

and give off "oxygen" as the "plant" is illuminated.

In the second compartment (left side of Fig. 4) are three "plants," each illuminated from one side by a different colored light. This illustrates phototropism, or the growth reaction to light. Plants grown where they receive light from one side will bend toward the light. To obtain symmetrical growth they should be turned or rotated. Here one sees that it is the blue component of white light that is most effective, that green light is less effective and that red light has no effect at all in this growth response.

The central exhibit of this panel is a working model of a plant growing under different light intensities. When the visitor presses the button, he will note that as the light diminishes in intensity the plant grows taller.

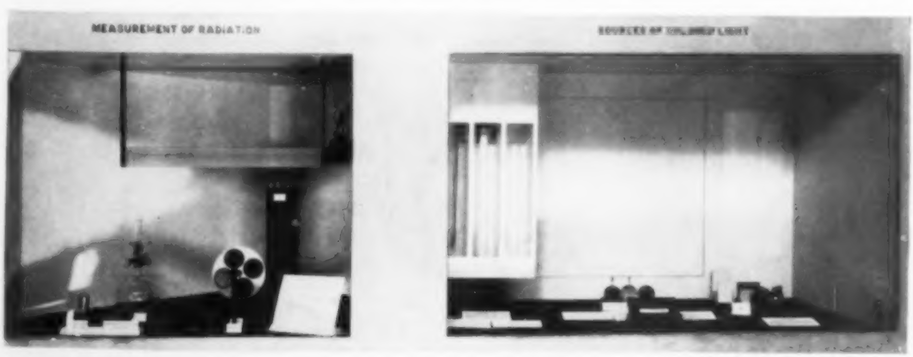


FIG. 2. MEASUREMENT OF RADIATION AND SOURCES OF COLORED LIGHT
THESE COMPARTMENTS ILLUSTRATE METHODS OF MEASURING RADIATION AND OBTAINING SPECIFIC WAVE-LENGTHS OF LIGHT.

The next space to the left is given over to the actual growing of algae on nutrient agar and in nutrient solution under artificial light. When the button is pressed, an enlarged image of an alga is thrown on a white screen in the upper compartment. Algae are the simplest forms of green plants, varying in size from microscopic single cells to multicellular forms many feet long. Because of their simple form, complete with all the life processes found in higher plants, algae are convenient for scientists to use in their researches on the effects of light, temperature and other environmental factors on photosynthesis, respiration and related plant processes.

FIG. 3. EXPERIMENTAL GROWTH CHAMBER
FOR GROWING ROOTS IN NUTRIENT SOLUTION UNDER CONTROLLED CONDITIONS OF HUMIDITY, TEMPERATURE AND LIGHT.

The last plant exhibit (Fig. 3) illustrates one method used in the laboratory for growing plants under experimental conditions. Plants such as wheat and barley are grown with their roots in nutrient solution and their tops in a double-walled glass tube where the temperature and humidity are controlled. To equalize illumination the plants are slowly rotated before light of known intensity and wave-length. The effects of different intensities and colors of light on chlorophyl formation, photosynthesis and respiration can thus be studied under controlled conditions.

The left-hand panel (Fig. 2) is given over to some physical methods that have been used in connection with plant and animal experimentation. As the visitor faces this panel he sees in the compartment on the right several devices for obtaining lights of various colors or wave-lengths. By pushing one of the electrical switches a beam of white light is sent through a prism and broken into the colors of the spectrum. The operation of a small disk will cause a slit to pass across this spectrum and the operator may select any color to be thrown on the small rear screen.

Another push button operates a lamp which sends beams of light through three different filters, glass, Christiansen and liquid. A colored glass filter absorbs certain colors and transmits others. A red glass filter, for example, absorbs violet, blue and green, and permits red light alone to pass through. This is also true of colored solution filters, with the

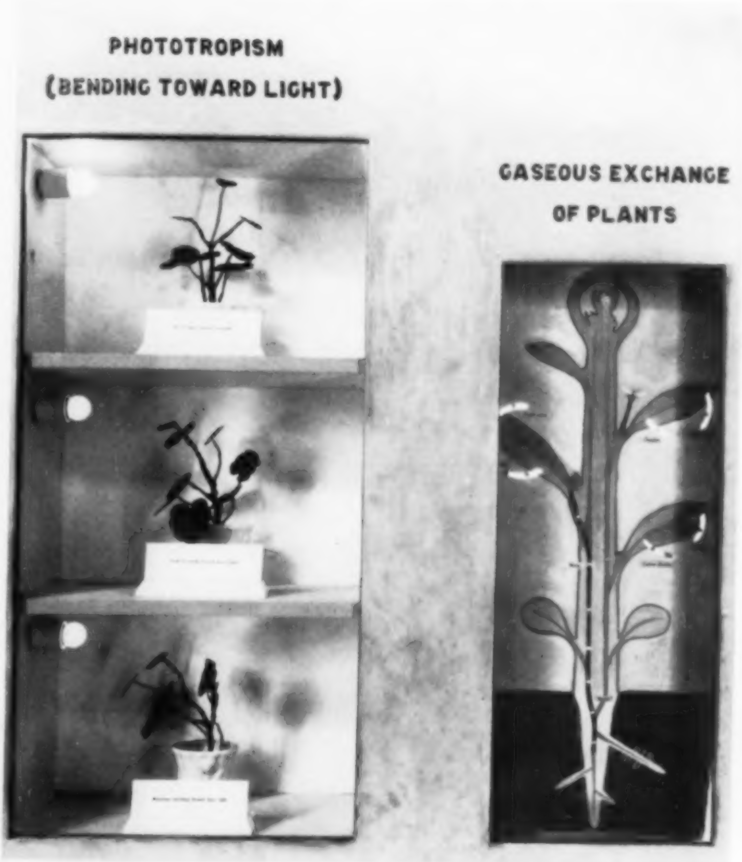


FIG. 4. DEMONSTRATIONS IN PLANT PHYSIOLOGY

THE LEFT COMPARTMENT ILLUSTRATES GROWTH OF PLANTS TOWARD LIGHTS OF DIFFERENT COLORS: RED, GREEN AND BLUE. THE RIGHT COMPARTMENT ILLUSTRATES THE MOVEMENT OF WATER UP THE PLANT STEM, THE EVAPORATION OF WATER FROM THE LEAF AND THE EXCHANGE OF CARBON DIOXIDE AND OXYGEN IN RESPIRATION AND PHOTOSYNTHESIS.

advantage that many shades and depths of color may be obtained by dilution and concentration. The Christiansen filter provides colored light in another way. A mass of small glass particles is immersed in a liquid having the same refractive index as the glass for the desired color. Since no light of this color is reflected or refracted (bent) at each small glass surface, this color is freely transmitted and is brought to a focus by the lens. All other colors are reflected or changed in direction and so are lost.

Another method of obtaining colored light is the use of discharge tubes. The visitor may operate another electrical switch and light a Neon lamp, in which the neon atom emits only red light when subjected to high voltage excitation; a mercury vapor lamp in yellow glass which transmits the yellow-green wavelengths; and a fluorescent lamp which makes use of the fact that some materials emit visible light (fluoresce) when exposed to ultraviolet rays.

The other compartment (on left of Fig. 2) in this panel shows certain types of apparatus for the measurement of

radiation. A button operated by the visitor turns on a lamp that directs a beam of light to the receiver of a thermocouple, where it is converted into heat. This energy is converted into electrical energy that activates a galvanometer, and the intensity of the light is measured on a scale. By turning a small disk different colored glass filters may be interposed in the beam of light and the relative transmission of these filters measured.

Other instruments shown here are photoelectric cells of the barrier type and the emission type, and the bolometer, a Smithsonian-developed instrument for the measurement of radiation.

EARL S. JOHNSTON

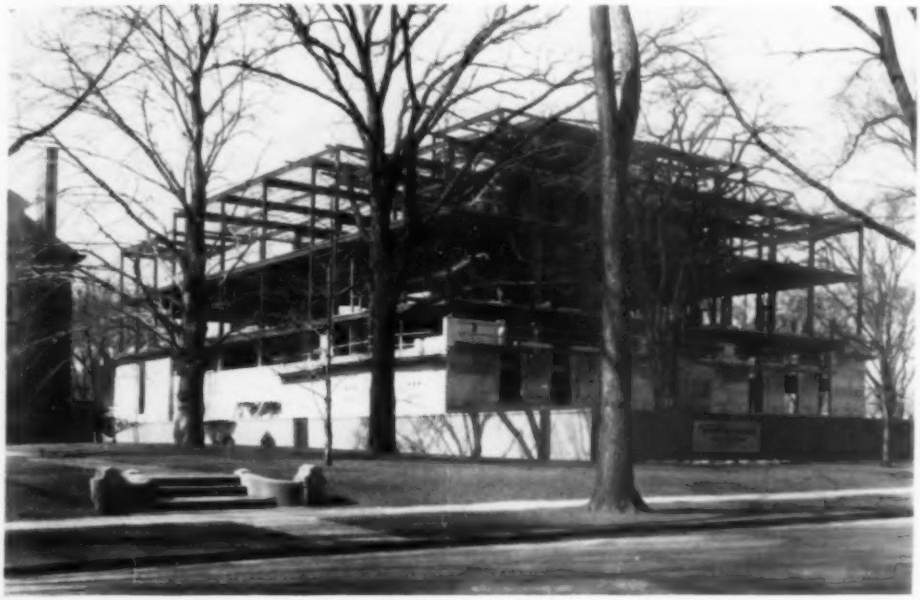
BAUSCH HALL OF SCIENCE AND HISTORY OF THE ROCHESTER MUSEUM

THE forward-looking plans of the Rochester Museum of Arts and Sciences have been greatly advanced through a gift by Edward Bausch, the microscopist, of funds for the erection of a new central unit. This building, which is now nearly completed, has been named the *Bausch Hall of Science and History*, the cornerstone having been laid on April 23, 1941, by Dr. Robert A. Millikan.

The building was designed especially to house the laboratories, studios, workshops and offices of the museum staff and will be equipped with the modern electrical devices and instruments necessary to carry on a research laboratory and popular program in the fields of natural science and physics.

The exhibition halls, of which there will be three, will present the story of nature from the phenomena of the stars, the geological ages, the beginning of life and the several phyla, ending at the entrance hall with dioramas of the larger local mammals, including the beaver. The stairway and elevator then convey the visitor to the second floor which, by diorama and exhibit, will tell a story of ancient man in Europe and in America,

ARCHITECT'S DRAWING OF THE BAUSCH HALL OF SCIENCE AND HISTORY



HALL UNDER CONSTRUCTION; PHOTOGRAPHED IN MAY

up to the coming of the white man. The third floor continues the drama of culture by presenting the great episodes in the culture history of western New York. This will be done in a series of alcoves which will portray in miniature and by actual-sized period rooms, the struggle of the pioneer up to the coming of the industrial age. A new wing has been projected to carry on this sequence and describe the progress of science and invention.

By developing a museum of science which merges into the field of culture history and industry, the museum will endeavor to present in cross section the salient features of upstate New York carrying out through its exhibits the inscription which is engraved at the top of the building:

DEDICATED TO A BETTER UNDERSTANDING OF THE LAWS OF NATURE AND CULTURAL ACHIEVEMENTS OF MANKIND

The new central unit will have its own printing plant, its biological laboratory with many unique features and a radio control station which will include sound recording and television reception.

A mezzanine floor between the first and second floors will house a school service program designed especially for children.

Dr. Bausch has assured the museum commissioners and the director that his desire is to make possible the carrying out of the existing plans which the museum has been attempting to achieve for a number of years.

The new Bausch Hall of Science and History is located in the heart of the residential section, on East Avenue, Rochester, N. Y., and is not far from Eastman House, the residence of the president of the University of Rochester. The Academy of Medicine is also located on East Avenue and is one of the sections of the Rochester Museum. Medical, anatomical and public health exhibits will be placed in the academy.

ARTHUR C. PARKER,
Director

ROCHESTER MUSEUM OF ARTS
AND SCIENCES

SOLAR WHIRLS

TITANIC flowers of fire on the face of the sun, with the dark areas of sunspots as their centers and long filaments of flaming hydrogen gas as their petals, are being studied by astronomers at the Mount Wilson Observatory of the Carnegie Institution of Washington. These great filaments, sometimes forming vortices or whirls long known to solar observers, are the subject of a special investigation by Dr. R. S. Richardson.

The normal surface of the chromosphere, or outer atmosphere of the sun, when viewed with the spectroheliescope under the best observing conditions, is seen to be finely granulated like the skin of an orange. Near large sunspots, however, there is a marked change in its appearance; the atmospheric gases are drawn out into long filaments, indicating the presence of extensive fields of force.

"Seen under the best conditions," Dr. Richardson says, "these filaments remind one of petals or tendrils growing out of sunspot penumbra and spreading over the hydrogen chromosphere. Occasionally they form a pattern similar to the arrangement of iron filings around a bar magnet, or to the lines of flow in a vortex." These filaments, he warns, must not be confused with the great polar prominences, geysers of fire thousands of miles high, which shoot up from the sun's face. They are smaller and lighter, though sometimes it is difficult to distinguish between the two phenomena.

Well-formed solar flowers are seldom observed. The late Dr. George E. Hale, formerly director of the Mount Wilson Observatory, found only 51 well-marked examples of them in observations of more than 3,000 sunspot groups between 1908 and 1924. Their cause is still debatable. Sunspots are known to behave like great magnets, and one explanation of them has been that the filaments are produced by magnetic forces. If this were the case, however, the direction of curvature of the "petals" would always be in accord with the polarity of the magnet. The fact that the polarities reverse from one sunspot cycle to the next, while the direction of the whirls *does not reverse*, argues strongly against the magnetic-field hypothesis of the whirls. Another theory, which seems more in accord with the present evidence, is that they are "whirlpools" in the sun's high atmosphere, whose form depends on how the gases are flowing into or out of the spot.

Dr. Richardson's own observations tend to confirm Hale's earlier results, and to support the hypothesis of atmospheric whirlpools. In the northern hemisphere their direction is mostly counterclockwise, like that of cyclones in the atmosphere of the northern hemisphere of the earth. In the sun's southern hemisphere they are mostly clockwise, paralleling atmospheric disturbances south of the earth's equator. If this is true, the inference is that the direction the vortex takes is determined largely by the solar rotation, just as the opposite directions of motion in cyclonic disturbances in the two terrestrial hemispheres are produced by the rotation of the earth.—S. W.